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IRON AND STEEL ENGINEER

DECEMBER • 1940

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Published Monthly by

ASSOCIATION OF IRON AND STEEL ENGINEERS

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879

Statements and opinions given in articles and papers appearing in "Iron and Steel Engineer" are the expressions of contributors, for which the Association of Iron and Steel Engineers assumes no responsibility.

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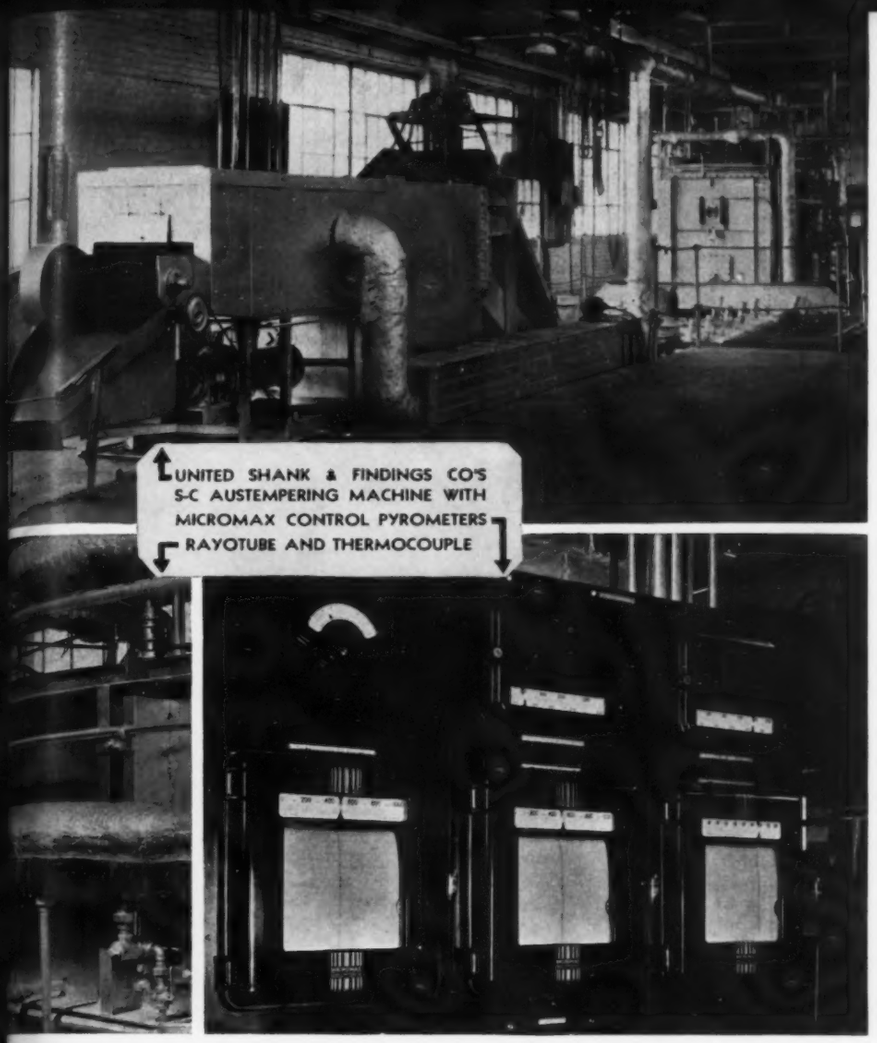


ROMAX PYROMETERS *Control* HEAT IN BIG AUSTEMPERING MACHINE

Orders Various Temperatures In Various Ways To Meet Heat-Treating Needs

Each hour from 500 to 700 lbs of flat steel springs are heat-treated in the austempering equipment shown above. The springs are hardened in controlled atmosphere, quenched in salt, washed, rinsed and dried. There's no scale; original surface is intact; hardness is 54-56 Rockwell C.

The varied needs of pyrometric control are met by Micromax pyrometers and accessories: To make sure the parts are hot enough when quenched, a "Rayotube", which "looks in" directly at them, and is considerably more responsive than the usual thermocouple, is focused on them. Since no record is needed here, the Rayotube is connected to a Micromax non-recording controller. Other temperatures are detected by thermocouples, with either Micromax recording controllers or non-recorders, to supply the desired information.

Despite varied requirements, only one type of valve-drive is used — the Micromax Electric. Each meets perfectly its load and lag situation, and gives full Micromax sensitivity from couple to valve.

For general information about dependable control, write for Catalogs N-33A and N-00B.

← Before austempering and after—steel springs show no distortion, no scale, no decarb

"Instruments Pay" Says Caterpillar Engineer

"We have a total of 300 instruments in our various heat-treating operations, exclusive of those in the laboratories" writes Charles E. Armstrong, Plant Engineer of Caterpillar Tractor Co., at Peoria, Ill., in the magazine *Factory Management & Maintenance* for October.

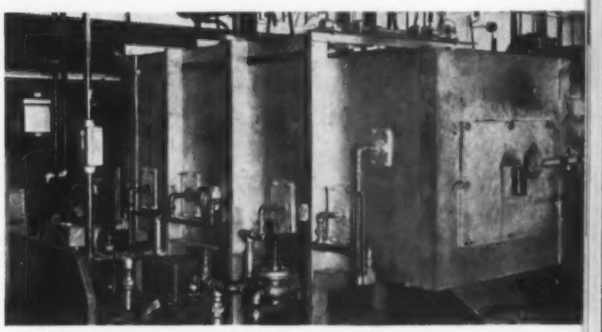
"The point of having all this equipment" Mr. Armstrong continues, "is that it permits precise regulation of temperatures . . . fuel savings . . . and reduces rejections on Brinell and similar inspections."

Caterpillar feels that "any one of the three savings is more than sufficient to pay for the instrumentation including carrying charges and the instrument men's salaries."

The article cites a case in which Caterpillar overcame a tendency of batch-type furnaces to overheat at one end. Other cases concern cyanide pots, low-temperature furnaces, and high temperature equipments. Each is explained in clear, non-technical words and the remedy is similarly given. Illustrations show some of the control equipment employed.

Gets Close Heat Control By Using Both "Rayotube" And Couples on Furnace

An up-to-the-minute method of controlling large furnaces is to supplement the usual thermocouples with "Rayotubes", at points where greater sensitivity of control is desired.



Norma-Hoffmann Bearings Corp. uses this Micromax-controlled shaker-hearth furnace in hardening of races

On this shaker-hearth furnace, for example, are two Micromax control pyrometers. One, a non-recorder, is connected to a couple in the forepart of the furnace, and acts through a Micromax Electric Valve Drive to regulate the earlier stages of heating. This is, of course, a standard arrangement, used in hundreds of plants.

The other recording Micromax, however, is connected to a "Rayotube" instead of a couple. And the "Rayotube" is focused directly on the parts to be hardened, at the point where they plunge into the quench. It is inherently more sensitive than a couple, and furthermore catches surface temperature rather than furnace-atmosphere or refractory temperature. It thus earns the lion's share of credit, by preventing practically all variations in hardening temperature, so that rejects due to hardening are all but unknown.

For descriptions, see Catalogs N-33A and N-00A.

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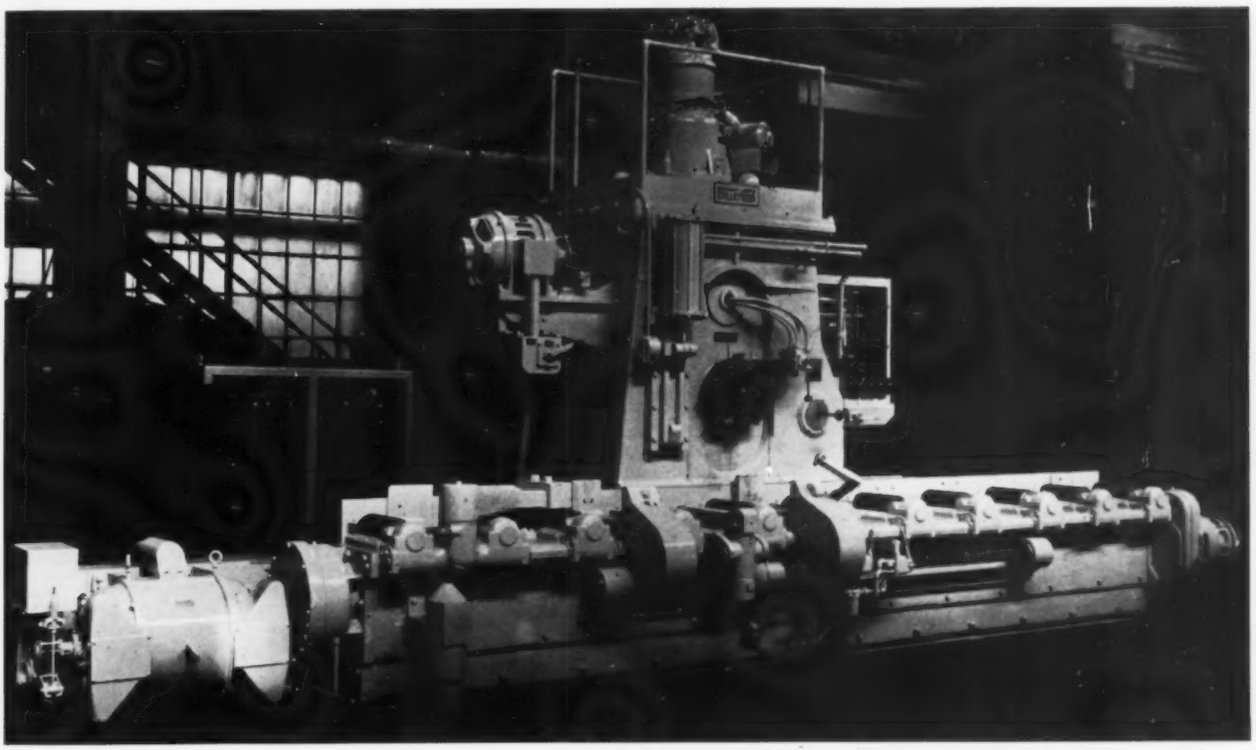

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To quote the plant superintendent: "The grease formerly used on our difficult bearing lubrication job would not withstand the moisture conditions encountered. It gummed up the bearings – power costs jumped as much as $250 per month. * "On the recommendation of Tide Water engineers we changed to Tycol Green Cast Greases because of their superior lubricating properties, and their ability to resist the washing action of water. Bearings are now better lubricated and excessive power costs have been banished. And we were surprised and delighted to learn that 25% more cars may now be hauled per locomotive because of the reduction in frictional losses." » » » This operator, like hundreds of others using Tycol Green Cast Greases, gets better protection – more effective lubrication – per pound of grease. Here's the reason: Tycol Green Cast Greases are made from the finest cylinder oils available. A minimum of soap – a maximum of oil – is used. More lubricating oil per pound assures more economical lubrication. » » » Call the Tide Water representative or office for full details.

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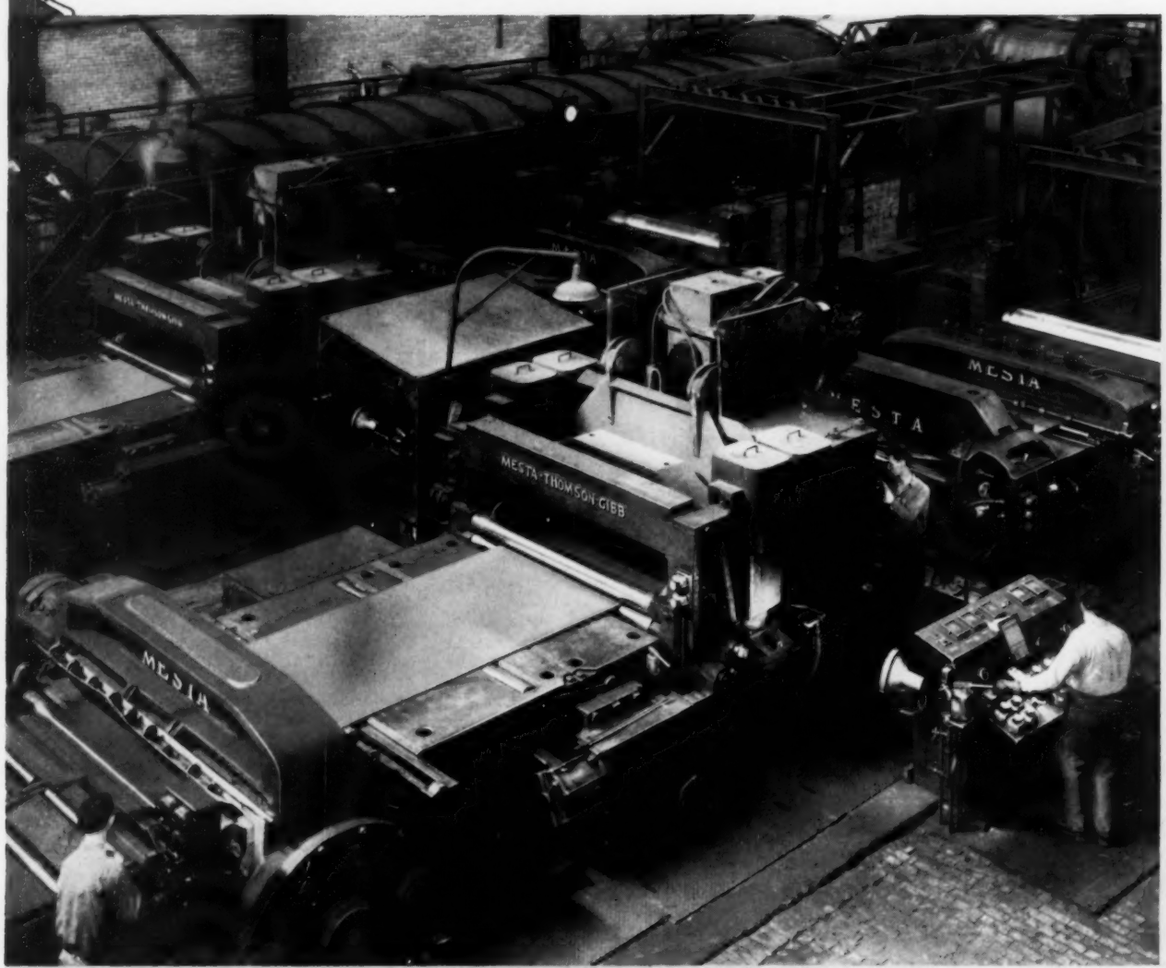

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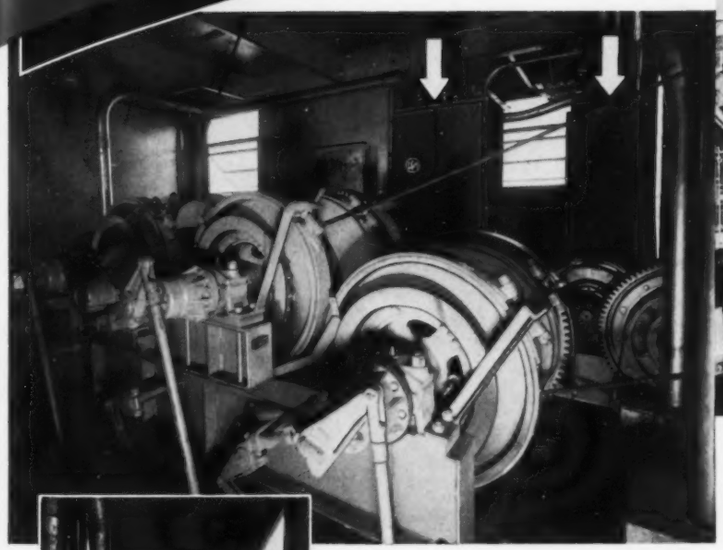
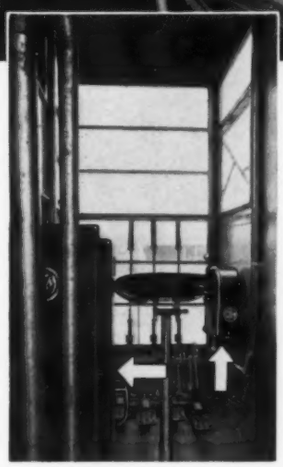
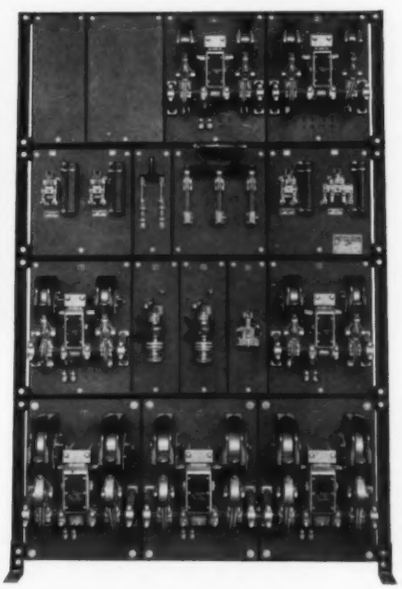




Interior views of above asphalt-handling crane showing EC&M Enclosed Controllers and EC&M Type NT Master Switch.



EC&M Reversing-Plugging Frequency Relay Magnetic Controller for Trolley Motion of Material-Handling Crane-Bridge.

CRANES powered with A-c motors are not new. Many are in use. They have been selected where the economies of using available A-c power have outweighed the better performance of a D-c installation. This has been particularly true of isolated installations where one or, at most, a few cranes are involved.

Highly satisfactory motors have been available for A-c as well as D-c cranes. D-c Control Equipment has been developed to a high degree of perfection — (examples, dynamic lowering control to eliminate the costly-to-maintain load-brake — the perfection of simple magnetic contactor control). ***The Development of A-c Crane Control has Lagged far behind.***

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Many installations of this control are now in service on overhead, boom, bridge and whirler cranes in steel mills, machine shops, ship-yards, cement mill, etc., service. There may be one in your vicinity which you can inspect. Write us.

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FREQUENCY RELAY System for A-c Motors

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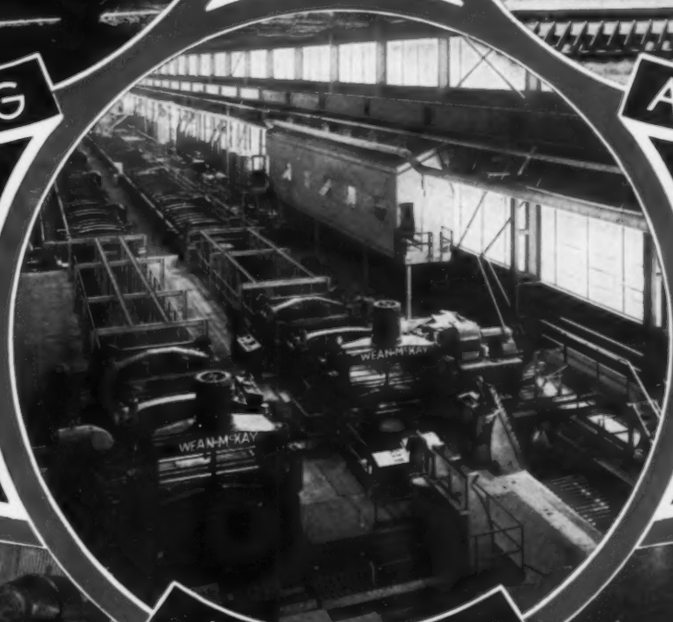

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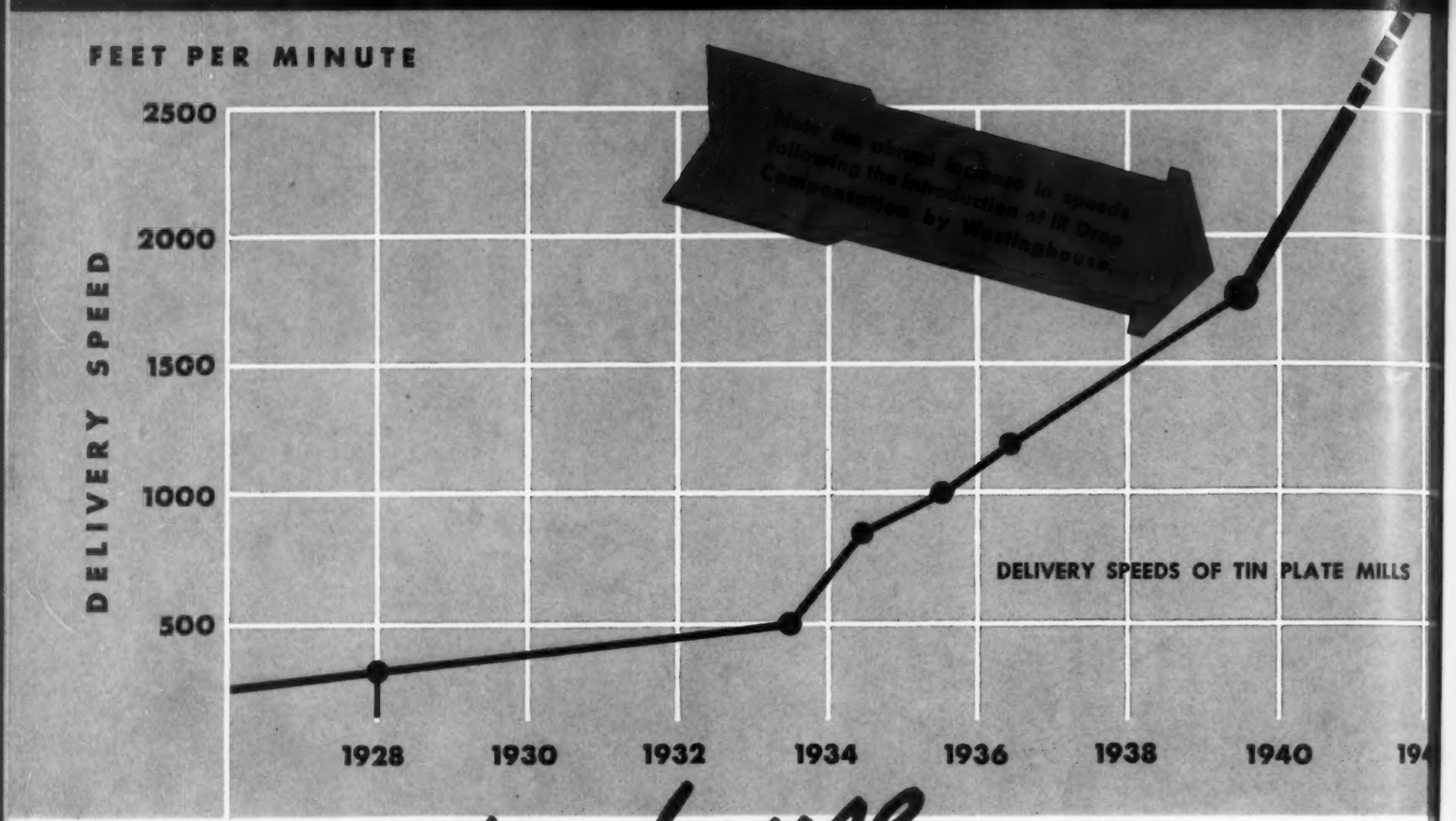

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From rolling speeds of 1750 feet per minute to 2500 plus—that's the increase in delivery rate of cold rolled tin plate since 1939 when Westinghouse first introduced IR Drop Compensation. And Westinghouse IR Drop Compensation has made possible similar spectacular increases in the delivery speeds of sheet mills, temper pass mills and processing lines.

This Westinghouse development maintains uniform speed relationship between motors driving the various mill stands—not only at the high rolling speeds, but also during the retarding, threading and accelerating periods. It insures the operator of immediate and accurate mill response regardless of relative loads on individual motors. Fast threading and rapid acceleration and retardation are accomplished. It materially reduces strip breakage and the amount of off-gauge product. J-94412

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Tune in "Musical Americana," N. B. C. Red Network, Coast-to-Coast, every Thursday evening.

Westinghouse

TIME-SAVER FOR AMERICAN INDUSTRY

DETERMINATION of Rates of Insulation DETERIORATION

By C. LYNN, Manager
Direct Current and Generator Engineering
WESTINGHOUSE ELECTRIC & MFG. CO.
EAST PITTSBURGH, PENNA.

Presented before A.I.S.E., Philadelphia District Section, April 6, 1940.

▲ DETERIORATION rates of insulation can be determined for any given set of conditions by tests, but even by such methods it is difficult to predict, by short time tests, the true curve of deterioration over long time periods, especially if the conditions of the tests are not severe nor near the upper limit of the insulation's strength either in temperature, voltage stress, or mechanical properties. In addition, the variations in the insulation limits of various classes of insulations, particularly when an insulation is made of several different types of insulating media, due to variation in the materials themselves and due to variations in manufacture; make predictions still more difficult.

It is, therefore, easy to understand why in the case of actual electrical machinery, where operating conditions cannot be predicted nor controlled, it is impossible to determine or predict insulation life or when failure is imminent, or when machines should be rewound or reinsulated. However, if consideration be given to service conditions and maintenance and if periodic tests be made, recommendations can be made as to methods of increasing insulation life and as to lengths of operating periods between rewindings.

Most insulations used on rotating electrical machinery are Class A as defined by the A.I.E.E. rules and it is primarily the failure of the organic materials in this insulation with which we are concerned. Such failures, generally, are due to what might be called oxidation of these materials. All insulations are treated with compounds or varnishes which give life, fill voids and provide some measure of flexibility and resiliency to insulations. When these impregnations are dried out, the insulations become brittle and are easily damaged and will not stand up under the forces and vibrations to which they are subjected in normal operation.

Insulation life depends upon many factors such as temperatures, electrical stresses, mechanical stresses and detrimental operating influences.

The temperatures of operation depending upon load conditions are ordinarily the greatest limiting factors in life of insulation. This, as has been mentioned, is dependent upon load cycles. Experiments have indicated that insulation life for class A material in rotating electrical machinery is doubled for a reduction of temperature operation in the neighborhood of 10 to 15 degrees C. Thus, it can be seen that if the temperature of operation is sufficiently low, approximate indefinite life will result, provided insulation is not subjected to other destroying conditions.

A.I.E.E. rules give 105 degrees C. hot spot temperature as the limiting temperature for class A insulation for continuous operation. Laboratory tests, which, of course, cannot duplicate actual operating conditions, and machines in almost continuous constant load operation, indicate that this limit was well chosen and with this limit over 10 years of operation can be expected. That machines with so-called class A insulation have operated at loads known to give higher temperatures than 105 degrees C. hot spot temperature for periods longer than 10 years, does not dispute the above, but only indicates that better materials were used. For instance, our company for over fifteen years has been supplying mica wrappers for ground insulation on the slot portion, mica tape for the end turns and in most cases, mica tape for conductor or strand insulation of armature coils for medium and larger size d-c. generators and motors for steel mill service. These coils are not considered class B coils but they are better than strictly class A coils because they employ a major amount of class B insulating materials.

Ambient temperatures, especially those of high value, such as exist around power plants in boiler rooms, result in short life if class A insulated motors are operated up to rated temperature rises under such adverse conditions.

Temperature cycles due to varying load cycles are destructive of insulation due to the chemical reaction that takes place. The higher the temperature, the drier it becomes, driving out the moisture and also insulating varnish solvents placed in the insulation during manufacture. This results in a chemical deterioration and mechanical brittleness. As the machine is cooled due to lower load operation or due to long periods of unprotected idleness, the insulation re-absorbs some moisture

and the process is repeated. The better impregnating varnishes and compounds fill the voids in the insulating material, the less this effect.

Temperature also has another bad effect on insulation and that is due to expansion and contraction. This effect is generally only pronounced on long core machines such as turbo generators, or long core d-c. motors such as reversing motors, where the insulation is chaffed by such movements, especially where the insulation in the slots has bulged into the vent ducts.

Electrical stresses are usually of no consequence in direct current motors and generators because the potentials are relatively low, usually 600 to 1000 volts maximum, with a few applications reaching as high as 3000 volts on some railway systems. On large size a-c. turbo and waterwheel generators the effects of voltage in the neighborhood of 6900 to 22,000 produce detrimental effects of corona and its products which produce a weak nitric acid, when combined with the moisture of the air which will attack all organic materials in the insulation, bracing twine, tapes, etc. It does not affect mica insulation. The complete filling of voids, rounding off all sharp corners with built up insulating tapes and the treatment of insulation surfaces with adquadag, to taper off the potential, minimizes the corona effects until they are of no detrimental consequence in modern designed machines in normal operation.

Mechanical stresses due to vibrations and rotational forces cause damage to insulation. Rapid accelerations and decelerations can cause minute movements of parts of coils or conductors which in time mechanically damage the insulation by abrasion. Where insulated conductors are not tight in slots, either due to too much clearance in winding originally or due to looseness of drying out or deterioration from excess temperature operation, cumulative damage will result to the coil insulation from mechanical stresses of operation or mechanical stresses set up by electrical load variations. Very good insurance against such detrimental effects can be secured by repeated hot dipping of the completely wound rotor and stator in insulating varnish with accompanying baking operations. In addition to giving a more complete homogeneous mechanical mass, moisture is more permanently excluded resulting in longer insulation life.

Next to temperature, more trouble is caused to insulation by damaging operating influences which consist primarily of oil and oil vapors, dirt and brush dust, moisture and gases.

Oil and oil vapor have the property of penetrating all kinds of insulation, resulting in damage to insulation from carbonization. Worse yet, particularly of commutating machines, where of necessity bare conducting parts exist, the oil acts as an adhesive for dirt and brush dust, both carbon and copper graphite, causing it to stick to the outer surfaces of the insulating windings. This forms a conducting path of relatively high resistance. Current, in the case of d-c. machines particularly, will flow along this high resistance path from one polarity to another or to ground and the heat generated in this high resistance path will cause the oil soaked insulation to carbonize and burn through, and eventually will lead to failure to ground.

The best method of determining the rate of such failure is by insulation resistance readings made from time to time. Machines in ordinary good condition should have an insulation resistance of several hundred thousand ohms to several hundred megohms, depending

FIGURE 1 *(left)*—Curves showing change of insulation resistance with temperature for class A insulation.

FIGURE 2 *(center)*—Curves showing insulation resistance variation with temperature for class B insulation.

FIGURE 3 *(right)*—Curve of minimum resistance at 75 degrees C. for new machines.

upon the size and voltage rating of the machine. Where insulation resistance measurements made recurrently over a period of time show no sudden large reduction in values and where the values themselves are relatively high, no trouble need be expected due to failure from low insulation resistance, but where the insulation resistance values fall rapidly and cannot be increased to appreciably high values by ordinary cleaning methods, invariably failure of insulation to ground will result. Often a thorough cleaning of the oil and dirt in cleaning liquids will remove the dirt and most of the oil and bring back the insulation resistance to a high value again. Where the insulation resistance again falls progressively with time, ultimate failure will result, necessitating rewinding.

On the a-c. windings of revolving field a-c. motors and generators, low insulation resistance is a signal of immediate attention, usually indicating the entrance of moisture, oil, etc., into the insulation or oxidation or carbonization of the insulation. Such windings are completely insulated up to and including the terminal connections of the leads so that dirt on the insulated windings cannot form conducting paths from line potential to ground or to opposite polarity.

In addition to dirt forming leakage paths to ground and from polarity to polarity on the insulation of windings of d-c. machines, leakage paths will be formed from the bare parts of the brush rigging or bare conductors of the commutating or series field windings, leading to ultimate failures or grounds if neglected. Removal of the conducting dirt by blowing, wiping or washing will clear up the low insulation resistance unless damage to the insulation has already resulted.

Insulation resistance is simply the measurement of the resistance in ohms to current flow from the copper conductors to parts of ground potential. A method of measuring this is to apply a given value of d-c. voltage to the conductors and ground and measure the actual current flowing through the insulation. Since the voltage applied and the resulting current flowing are known, the insulation can be determined by Ohm's law. Since the resistance is quite high, a relatively high d-c. voltage will be required to get a measurable current. Due to the accuracies required in measuring the low values of current to be measured, this method is generally limited to laboratory tests.

A more convenient method is to apply a source of d-c. voltage in the neighborhood of 500 volts and use a voltmeter of known resistance. The insulation resistance in ohms then equals the voltmeter resistance times the line voltage reading minus the voltage reading of the meter when it is connected in series with the insulation resistance and placed across the line, divided by the latter voltmeter reading.

$$R_i = r_v \frac{V_1 - V_r}{V_r}$$

where R_i = insulation resistance to be determined.
r_v = resistance of the voltmeter.
V_1 = measured voltage of supply line.
V_r = voltage read on the meter when it and the insulation resistance to be measured are connected in series across the supply voltage V_1.

A still more convenient method and the one generally used by operators is the insulation resistance meter or so-called "megger." This consists of a small portable unit with a hand cranked generator, delivering 500 or 1000 volts with a suitable meter directly calibrated in ohms or megohms resistance and for operation requires only the connections of two leads from the instrument to the insulation resistance to be measured. The operation of the generator gives a direct reading on the meter.

Another method used in laboratories and by manufacturers is the Wheatstone bridge method of balancing the unknown insulation resistance against a known value of resistance in a bridge circuit.

In taking insulation resistance measurements, the temperature of the winding should be known as the insulation resistance is appreciably affected by the temperature, the resistance decreasing with an increase of temperature. New machines always have the insulation resistance measurements made at the factory following full load heat runs. The insulation resistance of clean dry machines, to meet A.I.E.E. rules, should be in megohms equal to:

$$R_i = \frac{E_R}{\frac{\text{kva.}+1000}{100}}$$

where R_i = insulation resistance
E_R = rated voltage of the machine
kva. = rated kva. for a-c. machines and kw. for d-c. machines.

The following table shows the approximate variation of insulation resistance with change in temperature as determined by tests:

Material classification			Limiting observable temperatures, degrees C. (Industrial apparatus)		Insulation resistance constant per 10 degrees C.
Class	General	Examples	By therm.	By resis.	
A	Organic (impregnated)	Cotton, silk, paper, fullerboard, enamel.	90	95	44%
B	Inorganic (impregnated)	Mica, asbestos, glass.	110	115	63%

INSULATION RESISTANCE-TEMPERATURE EQUATION

$$R_T = r_t(C)^{\frac{T-t}{10}}$$

where R_T = insulation resistance at new temperature T.
r_t = measured insulation resistance at known temperature t.
C = insulation resistance constant.
T = new temperature, degrees C., at which insulation resistance is desired.
t = temperature, degrees C., at which insulation resistance was measured.

Example:

Insulation resistance of a d-c. armature with class A insulation at 30 degrees C. = 15 megohms.

What is insulation resistance when temperature is 55 degrees C.?

$$R_{55} = 15 \times (0.44)^{\frac{55-30}{10}} = 15 \times (0.44)^{2.5} = 15 \times 0.128$$
$$= 1.92 \text{ megohms}$$

Figure 1 shows change of insulation resistance with temperature and indicates an average safe range of resistance versus temperatures with class A insulation. Figure 2 shows insulation resistance variation with temperature for a class B insulated machine. Figure 3 shows curve of minimum resistance at 75 degrees C. for insulation resistance for new machines based on A.I.E.E. rules.

Oil is detrimental to commutator bar mica causing it to become eaten away from the conducting currents. Such oil leakage troubles must be eliminated to keep from any commutator bar mica failure.

Moisture in any form is harmful to insulation as before mentioned. Salt water atmospheres are particularly harmful due to the corrosive action of such atmospheres. Corrosive atmospheres are likewise detrimental to insulation and are to be avoided. It is impossible to tell the rate at which insulation is damaged by such factors as moisture or corrosive atmospheres, and where machines have to operate under such adverse conditions, experience will have to be the guide as to when failure is imminent or will result, and when rewinding will have to be undertaken.

From what has been stated, it can be seen that there are no mathematical or even empirical rules that can be rigidly applied to tell an operator of electrical machinery when a machine should be rewound because there are too many variables and no control possible over these variables. Data from insulation resistance measurements periodically made and experience gained by past operating conditions are the best indications of when a machine needs to be rewound. Where continuity of service is of prime importance, machines must be rewound before there is a chance of imminent failure. In other cases, it may be more economical to operate the unit until failure occurs.

One assurance for continued life of insulation is, of course, reduced load operation. It is obviously uneconomical to operate machines derated but machines can be purchased with higher temperature types of insulation. For instance, 40 degree C. rise d-c. motors and generators can be purchased still as 40 degree C. rise machines but specified with class B insulation instead of class A. Since class B insulation permits operation of 60 degree C. rise on the same basis as 40 degree C. rise for class A insulation, it can be seen that an additional margin of safety against failure is secured, not only on account of greater temperature margin but on account of the higher insulation resistance of class B insulation. Of course, this costs extra but within the past two years, many steel mills are adopting this procedure which will result in much longer life. Another advantage results in such procedure and that is overloads can be carried for longer times without damage to the insulation. This is of particular advantage in the case of d-c. motors for continuous mills where best rolling conditions may later dictate an increase of loading on a given stand motor beyond that initially calculated.

DISCUSSION

PRESENTED BY

G. C. PFEFFER, *Superintendent of Power*, Florence Pipe Foundry and Machine Company, Florence, New Jersey.

C. LYNN, *Manager*, Direct Current Generator Engineering, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

G. O. VAN ARTSDALEN, *Superintendent of Maintenance*, Henry Disston and Sons, Inc., Philadelphia, Pennsylvania.

F. O. SCHNURE, *Electrical Superintendent*, Bethlehem Steel Company, Sparrows Point, Maryland.

L. V. BLACK, *Electrical Superintendent*, Bethlehem Steel Company, Bethlehem, Pennsylvania.

J. E. ERICKSON, Public Service Gas and Electric Corporation, Camden, New Jersey.

WM. SIEBENMORGEN, Electro Service, Inc., Union City, New Jersey.

G. C. PFEFFER: Is there much work being done on glass insulation for large machines?

C. LYNN: Glass insulation came out approximately two years ago as far as the general public is concerned, and I believe the electrical industry thought of it as a sort of a saviour in general as far as insulation is concerned. In a way it is, and in a way it isn't. Some manufacturers applied glass insulation to such apparatus as magnet coils where it could even be run at a red hot temperature without failure because glass insulation can be operated at such high temperatures and still maintain insulated operating distances between the magnet wire without failure or breakdown before turns.

Obviously it cannot be applied in that same manner to a motor. After all, glass insulation is really only a weave, and if you examine it under a microscope, it looks like gunny sack material. In other words, it is not an insulation in the same sense as mica, which has dielectric strength and resistance to voltage, but only has insulation corresponding to the air insulation strength of the space it occupies in thickness. To make glass the universal insulation, an impregnant must be used before the spaces of the weave.

Considerable work is being done on developing such an impregnant that can be used at higher temperatures, but the goal has not yet been reached. When we do have an impregnant that will stand class B temperatures, glass insulation will have a much more widespread use than at present.

In some cases glass insulation has been applied on various machines, and in many cases has been the difference between failure and success.

G. O. VAN ARTSDALEN: We all know the deteriorating effects of oil and grease on class A winding, and we try to keep free of these conditions where possible. The only way to clean them, aside from rewinding, is to use a solvent, which may have greater deteriorating

effect. Has there been any successful solvent produced that has a minimum effect on class A winding?

C. LYNN: I don't know of any solvents that are perfectly harmless and that still will do the job. One that is widely used is carbon tetrachloride used with gasoline in a 50-50 mixture. This makes a liquid that is non-explosive. All the solvents that are now on the market will give about the same result, but it is better not to have to use them. If the oil can be kept away, that is the better thing to do, but sometimes it cannot be done as machines often operate in oily atmospheres. I do not know of any compound or cleaning fluid that will give the results which you would like to have.

F. O. SCHNURE: In reference to class B insulation, we have recognized the fact, particularly on continuous mills, that it is important to have a little extra capacity in some of the motors, because on some schedules they are apt to be burdened to a load and a half or more. Recently, in increasing the horsepower on a five-stand tandem cold strip mill, we put class B insulation throughout on the motor driving the last stand. Now we are going through the process of insulating one of the generators on this job with class B insulation.

However, the punishment that class A insulation withstands is sometimes a marvel to us all. On hard worked motors, subjected to high peaks and heavy loads tending to move the winding, the life is apt to be short, whereas on windings not liable to such conditions we have had excellent results with class A insulated motors operating under class B conditions. Needless to say, the application was not premeditated.

L. V. BLACK: I enjoyed Mr. Lynn's paper very much. He mentioned that probably one cure for failures of armatures or motors would be frequent dippings. I can readily understand that process for new motors or pieces of equipment, but, after all, we anticipate that a new job will give us very good service and only after the motor or armature is in service for some time do we expect insulation deterioration and eventual failure.

It would be very nice if we could periodically take our armatures out of the motors, dip them in some kind of solvent to remove dirt and grease, bake them to remove moisture, and dip them several times in varnish, but that would get only the outside of the coils and would not reach the iron and laminations at the location where most of the failures occur.

I think most of us would feel a little backward about taking resistance readings on most of the motors we have had in service ten or twenty years—I think we'd get heart failure—so after all, the least said about that and the least done about it, the better.

C. LYNN: I agree with what Mr. Black has said about the treatments of armatures occasionally. I would like to mention that the leakage currents that flow across the dirt, oil and carbon dust actually produce heat, and if we can bake and clean the windings and get a new varnish surface on them, better results will be secured. Of course, that is the ideal to look forward to. I think a lot of people get "mental trouble" on insulation resistance by taking megger readings; in the same manner that if you took a medical book and went through it, you would probably find some sickness that you have.

J. E. JENKINS: What is the maximum voltage they have now for rotating a-c. machines as far as insulation is concerned?

C. LYNN: It is uneconomical to go above approximately 20,000 volts. If small size machines were made for high voltage, so many coils of wire would be required and so much thickness of insulation that the space factor would be very poor. This would mean that you would lose out in capacity of the machine. On the larger size machines the space factor would be somewhat better on account of fewer number of conductors, but the ground insulation would be relatively thick. Therefore, voltages in the neighborhood of 22,000 volts is the maximum economical voltage for a-c. machines considered as a whole.

J. E. JENKINS: And what for d-c. machines?

C. LYNN: For d-c. machines it is uneconomical from the standpoint of design to use a voltage much higher than 600 to 1000 volts. The question here is not one of insulation on the armature, but of commutation and flashover. A few years ago we designed a machine of about 100 kw. capacity at 20,000 volts. This machine was to be used for plate voltage supply for radio transmitters. It was never built, for about that time large size rectifier tubes for plate supply came on the market. In the case of this machine, about 95 per cent of the armature slot space was taken up by insulation with only about 5 per cent left for copper.

J. E. ERICKSON: I have been secretary of the Power Maintenance Association of South Jersey for several years, and our maintenance men don't seem to worry about rotating equipment, but we have had several meetings at which some time was spent in discussing when circuit cables should be replaced because of the lowering valves of megger readings.

Mr. Pfeffer will probably remember several instances where members of the association have brought up the question of when, according to megger readings, cables should be replaced.

If megger readings are not a definite indication of insulation deterioration, what is?

That question may not follow Mr. Lynn's talk, but I would like to hear from some of the plant men here as to what they consider is a definite indication, or circuits, say, up to 13,000 volts.

C. LYNN: I am afraid that is a little out of my line, and I think if anybody is connected with a cable company here, they could probably answer the question adequately.

WM. SIEBENMORGEN: Mr. Lynn mentioned rewinding of machines. We have a chemical plant where the machines are subjected to fumes of sulphuric acid, failed, and had to be rewound periodically. We suggested that a certain time be given them after rewinding and that they then be reconditioned periodically as Mr. Lynn has suggested. That, by the way, has saved the company a great deal of money.

Then as to the point of insulation—that you don't want to measure resistance, etc.: I have not much experience with actual operation, but I see, when I go through large steel plants, armatures laid on racks, and

I was wondering what is done after a half year, when they are put back in. They are seldom in shape to go back. They are not in the condition the repair man or electric company left them. Surely you must have a method before you put them in, to bring them back to normal insulation resistance. Mr. Reed has reconditioned a 6000 hp. motor in this manner, and many other gentlemen did the same. I believe you should use that method.

And there is one more thing that might be mentioned; Mr. Lynn talked about voltage stresses. Many machines have mechanical stresses due to sudden rush of current. You take a 600 hp. induction motor thrown across the line to start a feed-water pump. These machines are all well made, but no care was ever taken to cope with the mechanical stress that the 6-times increased current on starting gives to the winding. Those windings have to be blocked, and made mechanically solid. This injury to insulation is perhaps outside the sphere of this discussion, but it does happen.

Then we have synchronous motors with large starting current—they go to pieces sometimes. If it is a large plant, the current they take doesn't matter much. Machines eventually go to pieces at the point where mechanical stresses are greatest on the winding at the time of starting.

C. LYNN: The only comment I have to make is that all of these rotors that have been reconditioned by the various steel companies have had treatments and bakings and are well protected before they are placed on the racks and before they go into the motors. While they are on the racks they are not subjected to all the dirt they would naturally get from normal operation because, of course, no volume of air is going through them. It would be better if they could be suitably covered to protect them from dirt and atmospheric gases. When a machine is in actual operation and has thousands of cubic feet of air going through it per hour, it is the dirt that is contained in this air which along with the oil vapor gives trouble from the dirt sticking on the windings.

As to the rest of Mr. Siebenmorgen's remarks, I think they are quite pertinent and need no further comment from me.

SECTION ACTIVITIES

BIRMINGHAM DISTRICT SECTION

JANUARY 27, 1941

"Design and Application of Tapered Roller Bearings for the Steel Industry," by S. M. Weckstein, Timken Roller Bearing Company, Canton, Ohio.

FEBRUARY 24, 1941

"Engineering Research and Design of Motors for the Steel Industry," by A. M. McCutcheon, Reliance Electric and Engineering Company, Cleveland, Ohio.

CHICAGO DISTRICT SECTION

JANUARY 7, 1941

"Plastics versus Metals in Industry," by Dr. A. A. Bates, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

CLEVELAND DISTRICT SECTION

JANUARY 6, 1941 (CLEVELAND, OHIO)
JANUARY 7, 1941 (YOUNGSTOWN, OHIO)

"Recent Innovations in Salt Bath Furnace Practice," by William Adam, Jr., Ajax Electric Company, Philadelphia, Pennsylvania.

DETROIT DISTRICT SECTION

JANUARY 14, 1941

"Economics of Electric Furnaces for Steel Making," by Harold E. Phelps, Rotary Electric Steel Company, Detroit, Michigan.

PHILADELPHIA DISTRICT SECTION

JANUARY 4, 1941

"Regulating Devices," by C. R. Hanna, Research Laboratories, and Ralph H. Wright, Metal Working Engineering Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

FEBRUARY 1, 1941

"Premixed Combustion of Gaseous Fuels for Steel Finishing Operations," by E. B. Dunkak, C. M. Kemp Manufacturing Company, Baltimore, Maryland.

PITTSBURGH DISTRICT SECTION

JANUARY 13, 1941

Symposium: "Steel Plant Water Supply"

Authors: L. N. McDonald, Jr., Carnegie-Illinois Steel Corporation, Youngstown, Ohio.
H. N. Graham, Dravo Corporation, Pittsburgh, Pennsylvania.
H. H. Shakely, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.
E. W. Butzler, Hagan Corporation, Pittsburgh, Pennsylvania.

Design and Operation of GEAR DRIVES

By F. P. Dahlstrom

▲ THE subject of gears, or perhaps more specifically, gear teeth, is one which is a fascinating study. The working surfaces of gear teeth are often highly stressed, and when we consider these stresses, together with the sliding which occurs between the loaded tooth surfaces, one is not inclined to ask why gear drives sometimes give trouble, but rather to inquire why they operate as well as they do. The modern gear drive is a very efficient and quiet mechanism, and has permitted the development of high speed sources of power which, in turn, has resulted in overall savings in weight and cost.

Several interesting papers on this subject have been presented before the members of this Association, to which it has been profitable to refer, and with these as a basis, the writer will try to bring out and develop certain features which should help us in our problems of gear design and operation.

ADVANTAGES OF THE INVOLUTE PROFILE

A gear tooth is a cam, which in turn acts against another tooth, or cam. Many cam profiles have been suggested and used, but the involute profile is considered by most gear designers to be the best. The involute profile results in a uniform rise cam, the follower of which moves in a straight line, called the line of action. This line of action is tangent to a circle, called the base circle. This fact has been repeated many times, but there is a reason for repeating it again. Since the line of action is tangent to a circle, it must necessarily follow that the pressure angle, or direction of pressure on the shaft is constant. The involute profile, therefore, combines uniform pressure angle with uniform motion, and this fact makes the involute curve outstanding as a means of transmitting rotary motion from one cylinder to another.

The involute has other advantages; it can be generated directly from a straight sided rack, or from cutting tools which are generated from the rack profile; the teeth can be generated at one pressure angle and operated at another; or to state it in another manner, the center distance between mating gears can be varied without losing the inherent constant pressure angle, constant velocity relation of the involute profile.

As an example of some of the possibilities available to the designer, there is shown in Figure 1 three pinions having 11, 12 and 10 teeth respectively. All were generated with the same cutter; therefore, all mesh with the same gear, but with different pressure angles.

The middle pinion (12 teeth) is conventional. It will be noted that the teeth are undercut, but notwithstanding this, thousands of this type have been used.

The 11 tooth pinion at the left has much better proportions and is representative of the product which is now being supplied by practically all manufacturers.

The proportions of the 10 tooth pinion at the right have been carried to the other extreme. This design would be useful in special cases where the maximum possible ratio is required and the operation can be intermittent.

In Figure 2 are shown two base circles—each with several involute profiles equally spaced around the periphery. It will be noted that the distance between the curves is the same at all points. Three pairs of curves are in contact where noted at "C." A line through these points is tangent to the base circle.

The object of Figure 2 is to show the uniform action

Mr. Dahlstrom, who delivered this paper at the A.I.S.E. Annual Convention in Chicago, Illinois, September 24-25-26-27, 1940, is Development Engineer for Farrel-Birmingham Company, Inc., Ansonia, Connecticut.

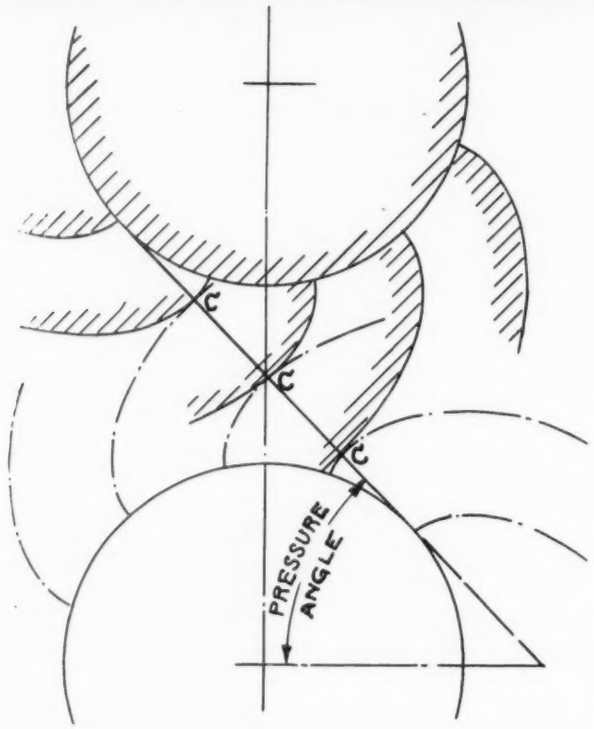


FIGURE 2—Sketch showing two base circles, each with several involute profiles spaced around the periphery.

of the uniformly spaced involute tooth profiles, together with the uniform pressure angle.

In actual practice there cannot be three profiles in contact in the manner shown in Figure 2, as there is hardly room for the long profiles, shown, to say nothing of teeth of appreciable thickness.

FIGURE 1—View showing pinions of 11, 12 and 10 teeth respectively, all generated with the same cutter.

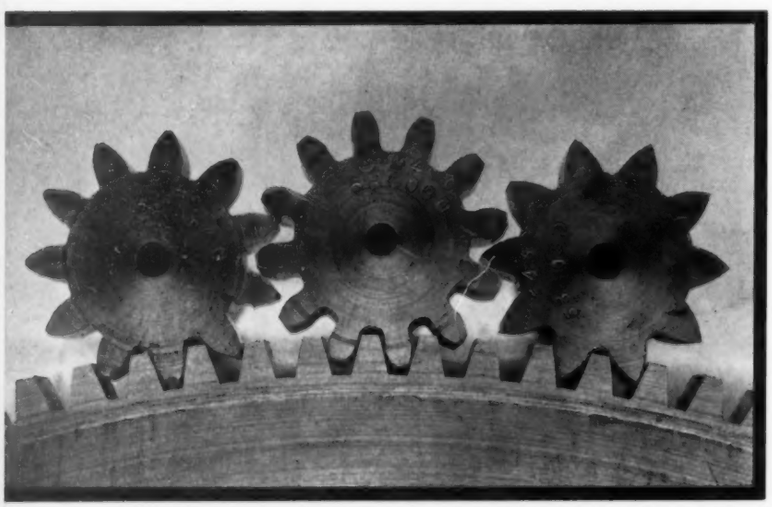


Figure 3 shows a more typical case. Here the active length of line of action is relatively shorter; it is that part of the total line which is included between the two outside circles. For spur gears this line should be at least one and one-half times as long as the distance between the involute profiles. This will insure that the second pair of teeth will be in engagement well in advance of the instant that the first pair of teeth travel away from each other.

ADVANTAGES OF HELICAL AND DOUBLE HELICAL GEARS

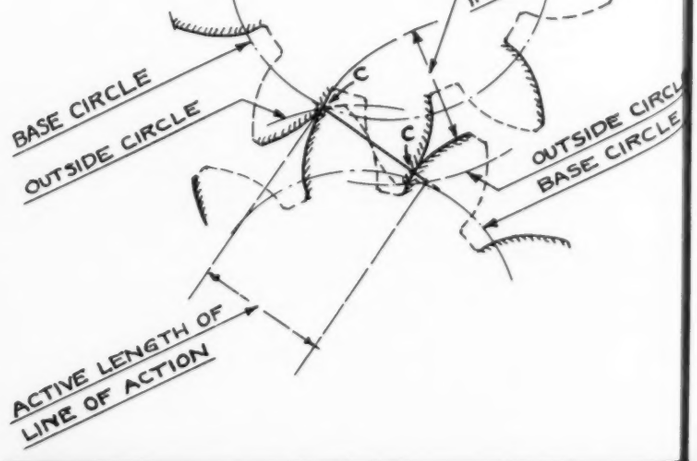
In Figure 3 two teeth are in simultaneous contact at "C" and "C." Slight rotation in either direction will result in one pair of teeth carrying the entire load.

It is evident that the teeth will deflect with load, even though the amount is very small. Because of varying numbers of teeth in contact, the compressive and bending stresses are non-uniform; therefore, the tooth deflections must also be non-uniform. This results in non-uniform transmission of motion, even though the teeth be perfect both in spacing and contour; a condition of perfection which any conscientious gear manufacturer tries to realize.

To overcome this inherent objection, the helical and especially the double helical type of gears have been increasingly used in gear drives. Not only are there more teeth in simultaneous contact, but the motion is more nearly uniform as each tooth has always a representative condition of all the various loading conditions.

It is important, therefore, that good alignment should be obtained so that the major part of the tooth face will be in use. This will prevent excessive load increase in a concentrated area, and also prevent a reversion from the inherent uniform motion of helical and double

FIGURE 3—This sketch shows two teeth in simultaneous contact at C—C. Slight rotation will give single tooth contact.



helical gears to the inherent non-uniform motion of spur gears.

The double helical type of gear has another advantage over the spur and helical gear, which advantage is often of help to the designer, especially as the reduction ratio increases. We refer now to the load concentrations caused by torsional deflection.

There is no advantage of the helical gear over the spur in this respect. The helical gear will tend to move axially, due to end thrust, but this movement cannot relieve the concentrated load at the driven end of a small pinion. Not only does torsional deflection tend to cause a load concentration at one end, but this same concentration tends to cause a change from helical gear operation to spur gear operation, as previously described.

With the double helical type, if one helix is loaded more than the other, the pinion will move endwise until both helixes will share the load equally, thus not only eliminating the end thrust, but greatly reducing the load concentration. If there were no beam deflection of the pinion, we might reasonably say that a herringbone pinion—of small diameter and relatively long length—would have twice the load carrying capacity of a helical gear having the same dimensions.

METHODS OF DETERMINING LOAD CARRYING CAPACITIES

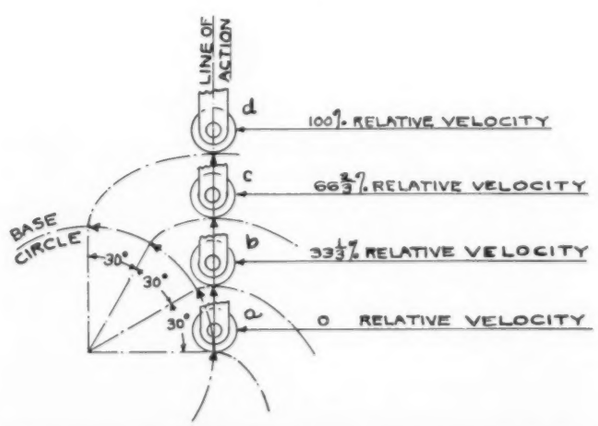
In the days of cast iron gears having cast teeth, the designer's main problem was the breaking of the gear teeth.

Wear was considered to be a normal condition. In 1892, Wilfred Lewis submitted his beam strength formula which determines the load gear teeth can sustain without breaking. The formula is basically correct and has been in use since its presentation.

The cast irons in use at that time were weak in tension, which condition limited their load carrying capacity. Because of this and also because of the presence of graphite, such gears did not show excessive wear.

With steel gears, however, at least three times the tooth load could be imposed without breakage. This

FIGURE 4—In this sketch, four equally spaced profiles represent four positions of a cam.



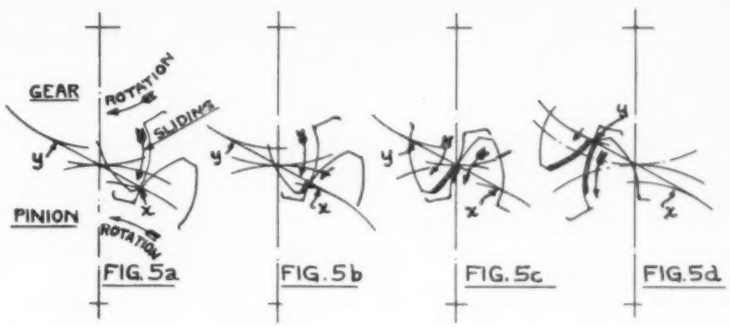


FIGURE 5—This sketch shows two gear teeth in four different contacting positions along the line of action.

solved one problem, but the surfaces of the tooth profiles were often over-stressed and the problem of wear then became a major one.

The word wear covers a multitude of conditions. For the present we will confine it to the phenomenon of surface destruction of a gear surface by pitting or spalling.

We speak of the line of contact between mating gear teeth. This line is of appreciable width. For small gears it may be $\frac{1}{64}$ in.—for very large ones it may be $\frac{3}{16}$ in. If a spur gear, 30 in. in diameter, is loaded to 3,000 lb. per in. of face, the width of the contact "line" between two teeth will be approximately .050 in. The compressive stress in the middle of this contact "line" will be 80,000 lb. per sq. in. A gear steel of 200 Brinell hardness will carry this load without pitting.

The use of the compressive stress method for determining the safe "wear" load for gear teeth was suggested in 1910. Since 1920 this method has gradually increased in use until now it has been practically universally adopted by gear designers.

The mechanical rating of speed reducers as sponsored by the American Gear Manufacturers Association is based on the compressive stress limits of the material used for the gears. (A.G.M.A. actually use shear stress. For gear surfaces in contact, shear stress = compressive stress $\times$ 0.3).

Essentially, this formula states that the permissible static load carrying capacity is proportional to the diameter of the pinion, times its face, times a material factor, which is based on the allowable stresses of the material. These stresses are substantially proportional to the Brinell hardness. The diameter of the gear which mates with the pinion also has its influence. The formula takes this into account and shows that a gear meshing with a rack will have twice the load carrying capacity of one meshing with a gear of the same diameter.

At very slow speeds the load which can be applied to the gear can be nearly equal to the permissible static load capacity. At a speed of, say, 3,000 ft. per min., the applied load often should not be over 30 per cent of the static load capacity for spur gears of average accuracy, and may be as high as 60 per cent for double helical gears cut with existing high grade equipment.

The word wear can also mean real abrasive wear, which conditions will be discussed, together with the remarks on sliding conditions of gear teeth and gear tooth failures, which follow.

SLIDING VELOCITIES OF GEAR TEETH

It will be recalled that the involute curve results in a uniform rise cam. In Figure 4 there are four involute profiles, equally spaced, which represent four positions of a cam.

The member driven by the cam is constrained to move in the line of action, which line, as before stated, is tangent to the base circle. Since the involute radius can be considered the amount "unwrapped" from the base circle, it is evident that the driven member will have four equidistant positions, "a," "b," "c," "d," as shown. The velocities of rotation of the roller in the driven member will depend on the lengths of the involute radii (indicated by the arrows of successive length).

If the velocity of rotation of roll "d" is 100 per cent for a given angular movement of involute profile, then in position "c," the velocity will be two-thirds; at position "b," one-third; at position "a," zero. We thus see that the velocity of rotation of the roll increases uniformly with the angle of rotation of the cam. The foregoing example will help in giving us a basic idea of the sliding of gear teeth upon each other.

Figures 5-a to 5-d show two gear teeth in four different contacting positions along the line of action. The line of action is represented by the line "x-y." Let us call the upper member the gear; it is shown rotating clockwise. The pinion at the bottom rotates counter-clockwise. Let us consider at first, only the pinion and the line of action. Referring to Figure 5-a, the pinion profile crosses the line of action at its beginning—point "x."

In Figure 5-b, the pinion has rotated a small amount, so that that part of the involute profile which intersects the line of action is a small amount higher on the involute curve. It is important to note that the shifting of the point of contact on the involute curve has been relatively small; it is indicated by the shaded area on the gear tooth adjacent to the point of contact.

In Figure 5-c, the pinion has rotated until the involute curve now intersects the mid point of the line of action. The line of action intersects the involute curve at the pitch line. The shaded area of the pinion tooth curve below the pitch line represents the entire amount of sliding which has taken place. Although the common intersecting point has traveled half way along the line of action, it has progressed less than one-third of the way along the involute profile.

In Figure 5-d, the pinion has rotated to a position where the point of contact is now at the outer end of its profile. As there is no more profile left, the line of action cannot extend beyond this point.

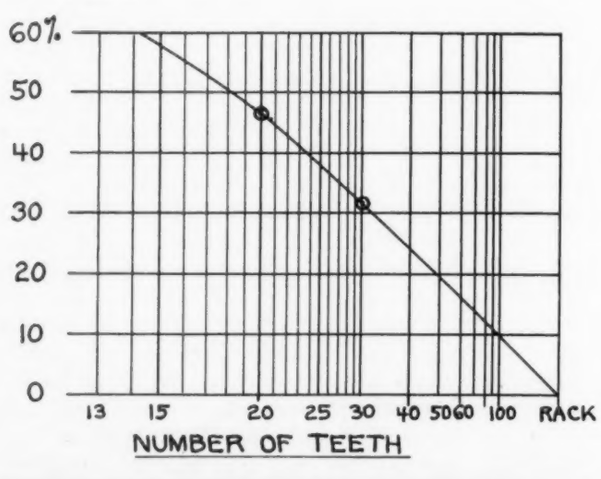
Referring back to Figure 5-a, the involute radius of the pinion at the point of intersection of the line of action, is very short. The sliding of the involute, relative to the line of action, will, therefore, be small. As the pinion rotates, the involute radius becomes longer; therefore, the sliding becomes greater. Thus, with uniform velocity of rotation, the sliding of the involute as above defined (that is, relative to the line of action), increases uniformly.

It will now be interesting to compare this statement with the preceding one made in connection with Figure 4, as follows:

"The velocity of rotation of the roll increases uniformly with the angle of rotation of the cam."

It is important to note that this sliding is always toward the center of the pinion (driver). Let us now include the gear in this picture. In Figure 5-a, contact is made at the outer end of the involute profile. The sliding velocity (as above defined) will then be maximum—in this case, always away from the center of the gear. In Figure 5-b, the sliding velocity has decreased

FIGURE 6—Curve showing relation of sliding velocity, expressed as percentage of pitch line velocity, to number of teeth.



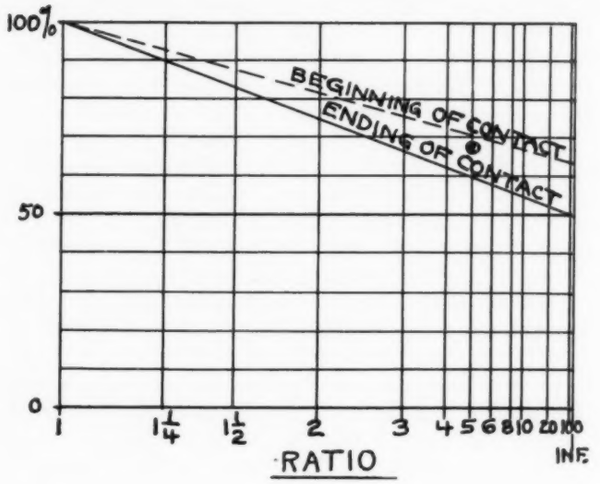


FIGURE 7—Curves giving relative maximum sliding velocities between teeth for pairs of gears of various ratios.

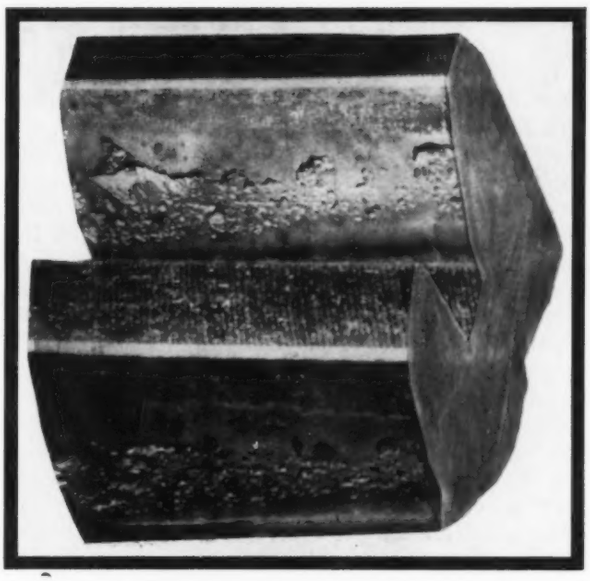


FIGURE 8—Typical example of failure by pitting and spalling due to excessive loading.

somewhat. It will be noted that the shaded area on the gear profile is much longer than the corresponding area on the pinion profile—about four times as much.

The relative sliding velocities of the gear and pinion in Figure 5-b (as well as 5-c and 5-d) are shown by the length of the arrows. It will again be noted that the arrow points toward the center (for the pinion) and away from the center (for the gear), but both in the same direction, relative to the line of action.

In Figure 5-c, the gear and pinion are now contacting at the pitch point. The sliding velocity of the gear has decreased from maximum; and the sliding velocity of the pinion has increased from minimum; at this position they are both alike. Since the direction is the same for both, there is no relative motion; therefore, the teeth are rolling.

From Figure 5-c to 5-d, the conditions are reversed. The sliding velocity of the pinion increases to the maximum value, while the sliding velocity of the gear decreases to the minimum value. It will be seen that while the sliding is distributed over the entire involute profile (addendum) outside the pitch circle, it is distributed over a lesser amount, about one-half, of the involute profile inside the base circle (dedendum).

From Figure 5-a to Figure 5-b, the ratio of sliding is much greater; the sliding is distributed over about four times as much of the gear addendum than of the pinion dedendum.

In the absence of correct lubrication, more wear should occur below the pitch line of the pinion, which is exactly what takes place. Even with a gear ratio of 1 to 1, we might expect that the rate of wear on the pinion dedendum should be four times as much as on the addendum of the gear.

The relative sliding velocity between the gear teeth is greatest at the beginning and ending of contact—Figures 5-a and 5-d.

In gears having few teeth, the lengths of the involute curves are relatively greater; therefore, the relative sliding velocity is greatest when the number of teeth is least.

ACTUAL SLIDING VELOCITY OF GEAR TEETH

The writer has calculated the sliding velocities between pairs of gears, one to one ratio, with tooth numbers varying from 13 to infinity.

The values have been plotted in Figure 6. The scale for sliding velocity is at the left, and is expressed as a percentage of pitch line velocity. The scale at the bottom for numbers of teeth is non-uniform. It is derived from a uniform scale in which the divisions are proportional to 1/number of teeth. This results in a plotted line which is nearly straight.

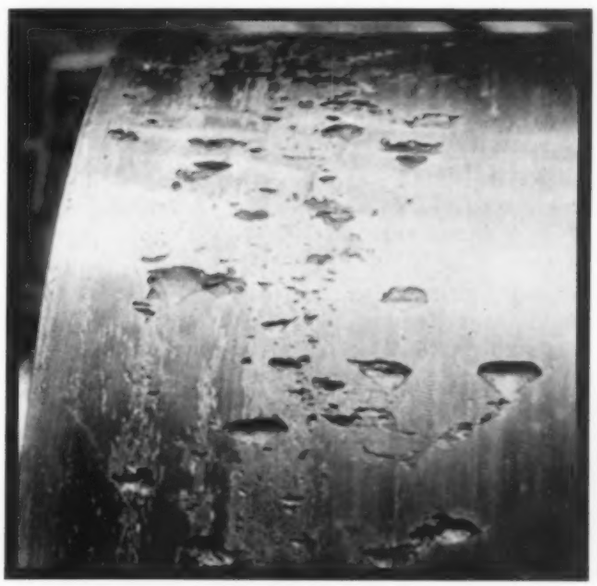
It is surprising how relatively large the sliding value can be. For instance, for gears having 20 teeth, the maximum sliding velocity is 46 per cent times pitch line velocity. The average sliding velocity is one-half = 23 per cent.

The writer next calculated the relative maximum sliding velocities between the teeth for pairs of gears from ratios of 1/1 to 1/infinity. In all cases the pinion has 20 teeth. The results are plotted in Figure 7.

The relative sliding (at both beginning and ending of contact) is taken as 100 per cent of pitch line velocity for 20/20 ratio.

With the ratio 20/rack, the maximum sliding velocity at the ending of contact is now one-half, 50 per cent. The maximum sliding velocity of the beginning of contact appears to be somewhat greater than one-half, as will be noted from Figure 7. The ordinates of the scale at the bottom are uniformly arranged according to 1/ratio, which resulted in straight plotted lines.

FIGURE 9—Surface failure on an unhardened steel roll after running about 100,000 revolutions in contact with hardened roll.



EFFICIENCIES OF GEAR DRIVES

The curves in Figures 6 and 7 help to enable one to more easily realize why gear drives are so efficient. Let us assume a drive 30/150 teeth at 2500 ft. per min. Referring to Figure 6, we find that with 30/30 teeth, the maximum sliding velocity would be 32 per cent times pitch line velocity. The average would be 16 per cent. Referring to Figure 7, with a ratio 5/1, the average relative sliding velocity would be 66 per cent as compared with 100 per cent for 1 to 1 ratio. The average sliding velocity would be 16 per cent × 66 per cent = 10 per cent of pitch line velocity, or 250 ft. per min.

Referring to the *Manual of Gear Design*, by Professor Buckingham, we find the coefficient of friction to be 3 per cent for a sliding velocity of 250 ft. per min. This seems reasonable; if it were much higher, the friction would be destructive and abrasion would occur.

The frictional loss will then be 3 per cent times 10 per cent = three-tenths of 1 per cent; in other words, the efficiency of the gear drive will be 99.7 per cent. This value is not so far from the facts as determined from carefully made tests.

GEAR TOOTH FAILURES

The failure of gear teeth, due to breakage, is now a rare event. Hardening of teeth (or tooth surfaces) permits greater load without wear which, when carried to the limit, makes it more important to check on the capacity of a gear by the Lewis formula. The correct number of teeth is thus determined for the conditions.

Pitting and spalling is due to loads in excess of the limiting compressive stress value for the hardness of material. A typical example of such failure is shown in Figure 8. The word failure is, perhaps, far-fetched, as the gear is still in operation after over ten years of service.

In Figure 9, there is shown the same type of surface failure on an unhardened steel roll after running approximately 100,000 revolutions in contact with a hardened steel roll. The surface of the hardened steel roll was still as good as when new.

With gears of substantially the same hardness and ratio, pitting will be more pronounced in the region below the pitch line. With increasing ratios, the pitting will tend to be increasingly confined to the smaller gear. In one case where the ratio is approximately 5 to 1, the writer did not find any appreciable pitting on the gear after several years of service, although pitting started on the pinion after a few weeks.

Galling and plastic flow is often due to insufficient lubricant. It may also occur with soft materials, even though the teeth are amply lubricated, in which case an extreme pressure lubricant will be helpful.

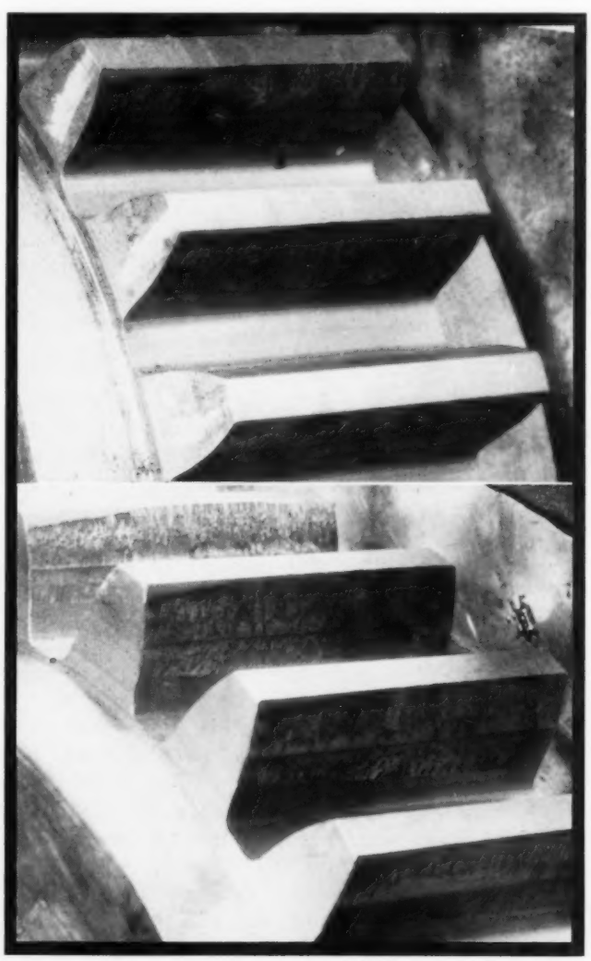
With gears of substantially the same hardness, galling and plastic flow will occur simultaneously on both pinion and gear. In all cases the direction of sliding is such that the driven member (gear) tends to abrade and plastically deform the pinion tooth surfaces away from the pitch line. In severe cases there will be found a groove in this region. Conversely, the pinion rubs against the gear so as to move the material of the gear toward the pitch line and consequently a ridge will form there. This phenomenon was discussed at greater length by the writer in the October, 1932, issue of the IRON AND STEEL ENGINEER.

To show how easily these conditions can occur, the writer deliberately ran a pair of gears together under conditions of insufficient lubrication. The condition of the driving gear after this test is shown in Figure 10-a. The teeth are badly abraded and deformed, and the characteristic groove can be noted at the pitch line. In Figure 10-b, which shows the condition of the driven gear, the characteristic ridge at the pitch line can be seen. As the surfaces of the teeth are rough, very little light is reflected from them.

The gears were then run together and a small amount of oil was continuously applied. The tooth surfaces soon acquired a polish and appeared as shown in Figure 11-a and Figure 11-b. The deformed tooth surfaces are now more clearly shown as they reflect more light.

These pictures show that the utmost precautions must be taken to insure that gear teeth never operate without lubricant. It is most embarrassing to gear manufacturers and customer alike when a condition

FIGURE 10—Views showing gear teeth after running with insufficient lubrication. Driver at top, driven gear at bottom.



occurs as shown in the Figures 11-a and 11-b. The manufacturer knows that at some time previous, a condition of insufficient lubrication must have occurred —but he often cannot make use of this knowledge.

LUBRICATION OF GEAR TEETH

The question of gear tooth lubrication is, probably, a more difficult one to discuss than that of materials. After all, our choice of gear tooth materials is, perhaps, more standardized and their ability to carry compressive stresses has been carefully studied. For example, during the last ten years, research along this line has been conducted at the Massachusetts Institute of Technology, under the supervision of Professor E. W. Buckingham. Some results of this work have appeared in progress reports of the American Society of Mechanical Engineers.

The science of petroleum chemistry is naturally not clearly understood by the engineer. He tries to design machinery so that it will operate successfully with the majority of lubricants available, and at the same time tries to take advantage of new improvements in the lubricant manufacturers' product.

In many cases, fortunately, it appears that if the compressive stresses are within the critical limit of the material, there is no serious lubrication problem involved. With harder materials, greater surface stresses (up to 250,000 lb. per sq. in.) can be carried. As the lubricant aids in transmitting these stresses, it must have all the "film strength" properties possible for it to contain. On the other hand, hard steels do not "gall" so easily, which is a help to both gear designer and lubricant manufacturer.

The most common gear lubricant for the modern enclosed gear unit is mineral oil. While animal or vegetable oils are more "oily" and have a greater actual lubricating effect, they are not stable enough to be successfully used in continuous service.

The first property, usually considered when selecting an oil, is its viscosity. Lightly loaded gear teeth (like other lightly loaded machine elements) can be correctly lubricated with an oil of low viscosity. Heavier loads require higher viscosity oils. Certain special oils have been developed for highly stressed gears. The introduction of the hypoid gear with its more pronounced sliding action was one of the factors in creating a need for such lubricants.

Subsequently, several special lubricant testing machines have been proposed and used for evaluating "film strength" of oils. So far as the writer knows, such data as are available show the film strength of lubricants as a function of viscosity at 100 degrees F. According to arbitrary standards for these machines, certain mineral oils break down at loads of, say, 8,000 lb. per sq. in., while especially prepared extreme pressure lubricants show a much higher film strength.

Certain of these machines have a rotating element which bears against a fixed element. It is evident that the local temperature must be very high. Galling is a high temperature phenomena. If the temperature of the oil is raised to the flash point, the viscosity of the oil at the rubbing surfaces may be considered to be very nearly zero.

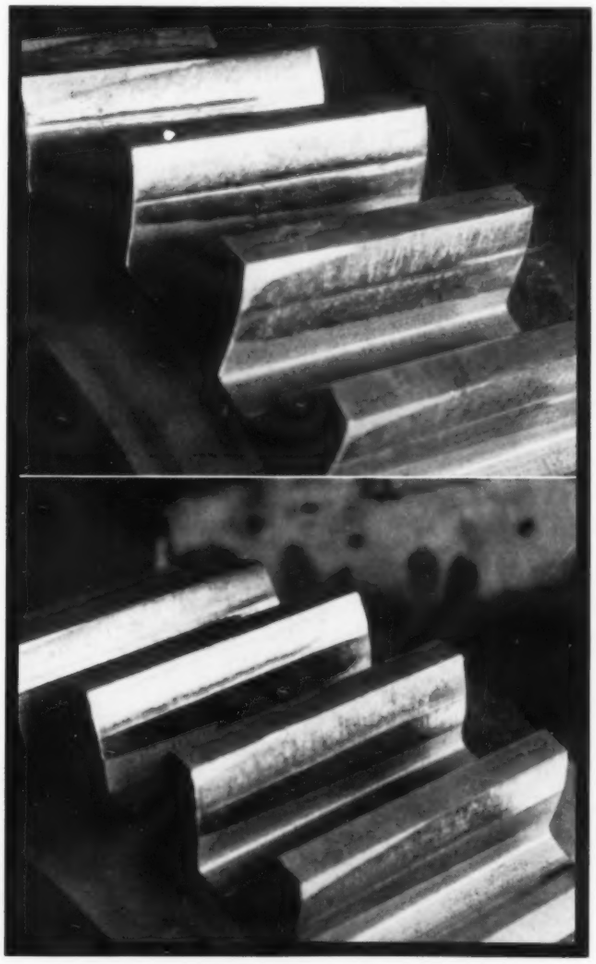
As a result of this line of reasoning, the writer has arranged a chart (Figure 12), showing the relation between flash point and viscosity. The viscosity scale is shown in seconds Saybolt at 100 degrees F.

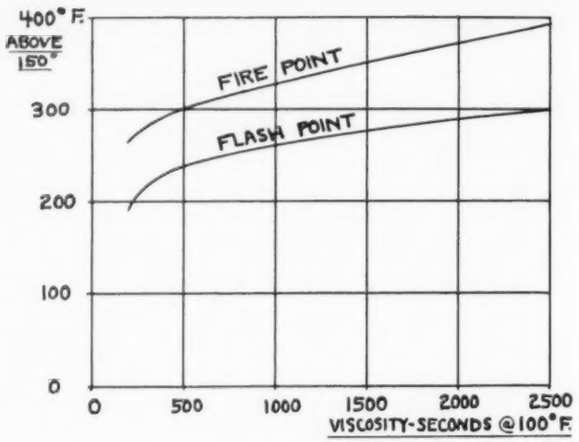
Instead of using the actual flash point temperature, the writer has subtracted 150 degrees F. from this temperature and this difference is the basis of the temperature scale.

In an enclosed unit it might be fair to state that the temperature of the oil as it enters the space between the teeth is 150 degrees F. The writer has assumed that the tooth pressure, together with the sliding which occurs under load, must raise the temperature of the lubricating "film" to the flash point before complete failure occurs.

Using 150 degrees F. as the zero line in the chart, we will now compare oils of various viscosities according to the method of reasoning above outlined. On the chart, it will be noted that the load capacity of the oil (on the flash point basis) drops off rapidly with viscosities under 500 seconds. Starting at 500 seconds, if we double the viscosity, we increase the temperature

FIGURE 11—The gears shown in Figure 10 were subsequently run with continuous lubrication, finally appearing as shown below.





NOTE: ZERO ON SCALE AT LEFT FOR FLASH AND FIRE POINTS IS 150° F. ABOVE ACTUAL VALUE.

FIGURE 12—Chart showing relation of flash and fire points to viscosity of the oil.

range only 12 per cent. If we again double the viscosity, we increase the temperature range another 12 per cent. Paraffin base oils have a 30 per cent greater temperature range than the asphalt base oils.

By this method of reasoning, it would appear that the increase of capacity with increase of viscosity (on the 100 degree basis) is small. In order to double the capacity, we would have to double the viscosity four times, which would result in a viscosity of 20 times the original. Such a conclusion might be reached if oils are tested on conventional testing machines where the load is continuously concentrated on a small area in such a manner that a true hydro-dynamic film cannot be established.

With gear teeth the situation is different. Two curved surfaces slide together at varying speeds and at areas which progressively shift across the gear tooth face. For a gear of, say, 30 teeth, the tooth surface is active, say, 5 per cent, of the total time of service. An area of the tooth surface, say, $\frac{1}{32}$ in. wide, may be in service only one-fifth of 1 per cent of the time, or to state it another way, for only 1/100 of a second during each revolution.

A newly oiled surface, say, at a temperature of 150 degrees F., is applied to the gear tooth surface, once per revolution. As the curved surfaces of the teeth come into sliding engagement under heavy pressure, we have the following forces to prevent metal-to-metal contact:

a—The natural adhesiveness of the oil to the metal.

b—The tendency to trap oil between the sliding curved surfaces, due to the "wedge action."

c—The resistance to displacement of the oil because of "a" and "b."

The resistance to displacement of a true hydro-dynamic film (such as may be built up by "b") varies with the viscosity. The work of displacement raises the temperature of the film. These two statements give us a further chance to evaluate oils.

Let us assume that the temperature of the film is raised to 210 and 300 degrees F. respectively. The two curves in Figure 13 show the viscosity of oils at these temperatures.

If we double the viscosity of oil at 100 degrees F., we increase it by one-third at 210 degrees, or only 15 per cent at 300 degrees F. The character of the 300 degrees F. curve is not unlike the flash and fire point curves in the previous figure.

To state the above in another way, the viscosity of oil at 210 degrees F. is proportional to the square root, or cube root (depending on the oil) of its viscosity at 100 degrees F. The viscosity of oil at 300 degrees F. is approximately proportional to the fifth root of its viscosity at 100 degrees F.

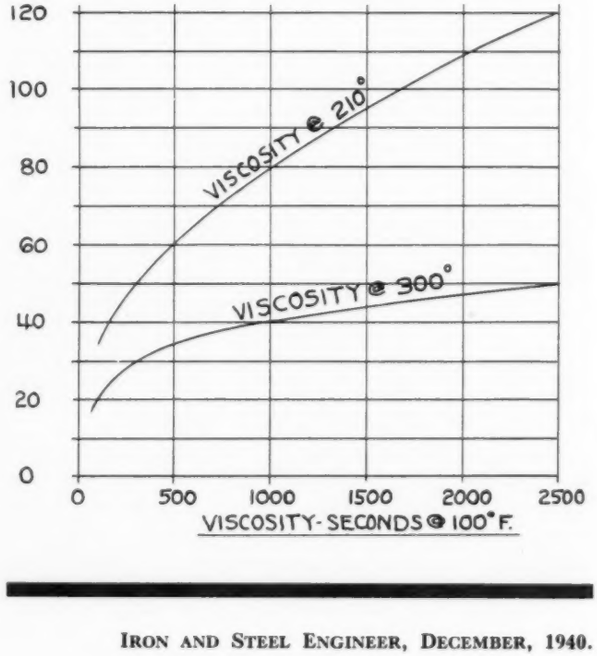
Based on these lines of reasoning, the writer suggests that for any given set of conditions, the capacity of a standard helical or spur gear drive varies as the square root of the viscosity of the oil at 100 degrees F.

When successful operation of a gear cannot be obtained by the use of an oil of higher viscosity, or by cooling the oil, it then becomes necessary to use an extreme pressure lubricant. Lubricants with fillers have been in use for several years with marked success in certain installations.

WHY DO GEARS OPERATE SUCCESSFULLY?

Tests have shown and experience has proven that the modern gear drive is one of the most efficient mechanical devices known. It has been shown by the analysis in this paper that the losses in the gear mesh should not be over one-half of 1 per cent. Gears and cams are examples of the relatively few machine elements that can operate successfully under high unit pressures, when the contacting parts are steel against

FIGURE 13—Curves showing relation of viscosity (seconds at 210 and 300 degrees F.) to viscosity at 100 degrees F.



steel. We could not use these materials for both shaft and bearing—neither could a worm gear operate successfully with a worm if they were made of steel—say, having a hardness of 200 Brinell. In both cases galling would occur.

Let us assume that the ultimate cause of oil film failure is high temperature, which, in turn, is caused when heat is generated faster than it can be dissipated. The amount of heat generated depends on the pressure, relative sliding and time of contact between the mating surfaces. With bearings, the time is 100 per cent, the relative sliding is 100 per cent; therefore, the pressure must, of necessity, be very low. (This refers to a construction where shaft and bearing are made of steel.) With gears, the time in any particular area is extremely small—only a fraction of 1 per cent; the relative sliding, from 0 to 30 per cent—therefore, the pressure can be much greater.

If we increase the relative sliding—as in the case of hypoid gears—we must decrease the unit pressure or use an extreme pressure lubricant, which lubricant, under the influence of high temperature, chemically reacts with the steel and aids in preventing "galling."

MAINTENANCE

The modern gear drive is a fine piece of equipment, the parts of which are made to great precision. It will be evident from the foregoing that the gear teeth should at all times be supplied with the correct lubricant. It also follows that when installing a gear drive, the utmost precaution should be taken to prevent the entrance of grit, which is always present during construction. Care should be taken to obtain correct alignment with mating equipment and a final check should be made of the gears, in order to be sure that they are not forced out of their normal running position because of outside influences.

Perhaps these few but most important suggestions might seem to be superfluous, but the fact still remains that investigations as a result of service calls too often reveal that one or more of these essential precautions have been overlooked.

On the other hand, attention to such details results in a long lived, efficient and quiet mechanism, the reliability of which can be shown by the brief summary of the use of gear drives which follows.

Previous to 1910, rolling mills were usually powered by slow speed, direct connected units. During the next ten years, gear drives were introduced which permitted smaller prime movers, with resulting economy of space, flexibility and lower cost. During the next decade practically all mills and auxiliaries were powered by high speed units with gear drives. The reliability of the modern gear drive is now so well established that many builders of electric motors are now including gear reduction units as an integral part.

The writer has tried to cover some of the general points of gear design and operation in such a way that the operating man will have a better conception of what a pair of gears is actually being asked to do, and hence be in a better position to select gears properly and especially to operate them successfully.

DISCUSSION

PRESENTED BY

W. P. SCHMITTER, *Chief Engineer*, Falk Corporation, Milwaukee, Wisconsin.

R. S. MARTHENS, *Works Manager*, Gearing Division, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pennsylvania.

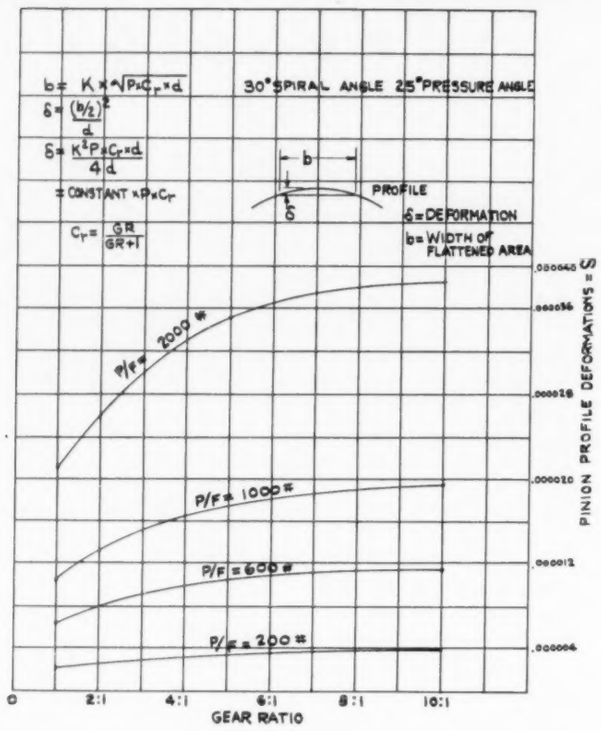
MAURICE RESWICK, *Lubrication Engineer*, Standard Oil Company of New Jersey, New York, New York.

E. W. BUCKINGHAM, *Professor of Mechanical Engineering*, Massachusetts Institute of Technology, Cambridge, Massachusetts.

F. P. DAHLSTROM, *Development Engineer*, Farrel-Birmingham Company, Inc., Ansonia, Connecticut.

W. P. SCHMITTER: Mr. Dahlstrom states, "If there were no beam deflection of the pinion we might reasonably say that a herringbone pinion—of small diameter and relatively long length—would have twice the load carrying capacity of a helical gear having the same dimensions." It is true that the double helical pinion deflection for a given set of conditions is lower than that of the single helical pinion. This may influence the designer's choice of proportions in some instances insofar as bending is concerned. Torsional deflection is never a serious factor with gears of present day designs. Take, for instance, the main pinion stands where external axial thrusts dictate the use of single helical pinions. The high torques which must be carried frequently make it necessary to use face widths of two or two and one-half diameters, yet we have never run into distress from torsional deflection nor, for that matter, failure from any cause.

The manner of pinion deflection is not generally understood. If we had to consider torsion only we could expect maximum concentration with two equal pinions having power input and take-off on the same side and complete compensation when located opposite. Theoretically, we would have half concentration when such a pinion meshed with a torsionally rigid gear irrespective of shaft take-off position. The situation with regard to mill pinions is somewhat different, the concentration arising solely from the magnitude of shaft twist from the torque carrying direct driven roll. However, these deflections do not occur anything like an abstract theoretical analysis would indicate, and fortunately so. This applies also to effects from bending. It is considered good practice in the highest grade gearing to limit the theoretical bending to .0005 in. over the face width. The elastic profile deformations normal to the tooth surface are extremely small even under severe loading (see Figure A), being only about one-tenth of the allowable transverse deflection of the pinion shaft. It is obvious that in order to obtain even reasonably good distribution of load, compensatory influences must be at work. The fact that the beam deflection of the teeth is of a materially higher order explains in part why extremely high concentrations do not exist in actual operation. We are so used to designing to avoid



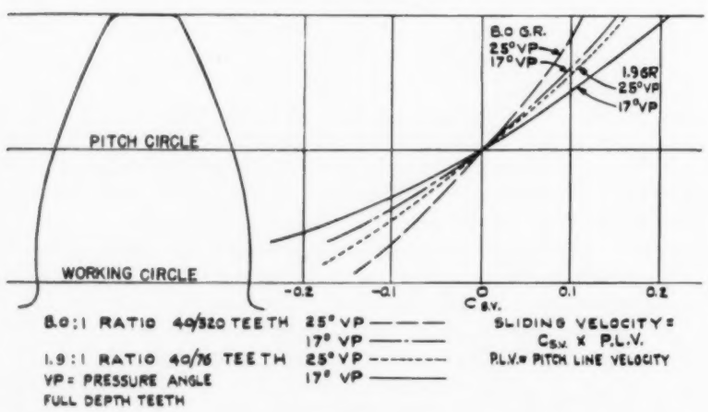
PROFILE DEFORMATIONS

FIGURE A

undesirable effects of deflection that we frequently forget that it would be impractical to operate gears at all if it were not for certain other desirable effects thereof.

The author has particularly emphasized the sliding of gear teeth. We frequently use what we term a C_{sv}: factor which, when multiplied by the pitch line velocity, gives the actual sliding rates. It will be noted from Figure B that the sliding decreases as the pressure angle goes up; also that it is a maximum at the low ratios and decreases with an increase in ratio, other conditions remaining the same. Unquestionably, sliding has some beneficial influences in sustaining load. It is also productive of undesirable effects. Apparently the specific stresses are increased over the theoretical in certain parts of the profile and decreased in others. Sliding rates may be varied over a considerable range, however, without unduly affecting capacity. The rate about doubles with all addendum teeth and yet the overall capacity may remain approximately the same. One interesting feature of the all addendum gear is the extent of the pitting at the limit load. Instead of concentrating at or just below the pitch line, it develops at all portions of the profiles of both members.

FIGURE B



SLIDING VELOCITIES

Sliding on 15 degree pressure angle teeth is considerably higher than for 25 degree teeth and yet there seems to be little, if any, difference in load carrying capacity providing the tooth height is such that the contact stresses are approximately equal.

It would be expected that the direction of sliding relative to rolling as well as the specific rates is a factor. The results of such roller tests as are available would seem to bear this out. The duration of contact is likewise considered important. Higher speed gears operate satisfactorily with lighter lubricants than do low speed gears.

The author has put forth an interesting theory as to the variation of capacity with the square root of the viscosity of the oil at 100 degrees F., but does not state the basis on which this conclusion was reached. We have not run any load tests at the flash point of the oil and, therefore, are unable to comment one way or another. He does not state whether the theory applies to pitting or scuffing, but I presume the latter. Pitting occurs more frequently at the lower speeds where we have low horsepower and high torque but where operating temperatures are very low. It is reasonable to say that scuffing develops when lubrication fails.

Gears are sensitive to any axial movement of the elements relative to each other. The high axial component of sliding in hypoid gears is the reason for their tendency to scuff except where extreme pressure compounds are employed. Helical or herringbone gears will scuff almost instantly if the pinions are agitated axially as in the case of critical speed phenomena.

R. S. MARTHENS: The author has covered in a general way some of the design and operation problems of industrial gear drives. As indicated by the author in the first part of the paper, almost all industrial gears today use the involute tooth form.

Not all gear designers would agree with the author's statement regarding the load carrying capacity of a herringbone pinion compared to a helical pinion of the same dimensions. For many years this has been a controversial subject.

The author discusses several methods of determining load carrying capacities. It may be of interest here to state that the American Gear Manufacturers Association have already adopted formulae for the various types of spur, single helical and double helical or herringbone gears.

A great deal of fundamental research work and laboratory testing has been done to determine the degree to which the adopted formulae are safe. In actual practice using the adopted formulae, relatively few industrial gear drives fail from tooth breakage, even under excessive overloads. Most failures occur from scoring or pitting. Scoring accompanies sliding

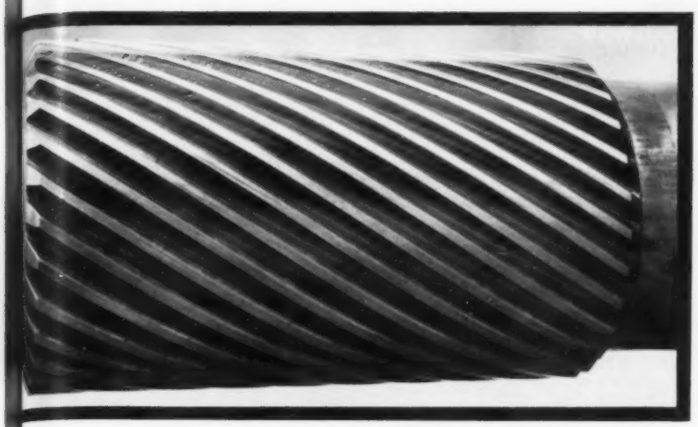
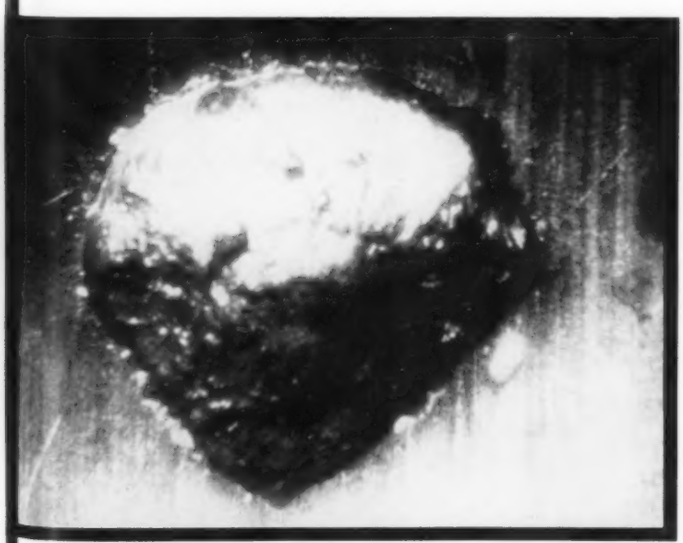


FIGURE 1

under heavy load of the tip of one tooth over the flank of the other at engagement. Pitting, on the other hand, can take place with pure rolling as well as with combined rolling and sliding and much larger particles are separated from the surface than in the case of scoring. Figure 1 illustrates a pitted pinion. Although a gear or pinion that is pitting is quite usable for the transmission of power, the operation is likely to be noisy, the life of the member is shortened and the lubricant is filled with metal particles which get into the bearings and further destroy the tooth surfaces.

To throw more light on the subject of pitting and its prevention, laboratory tests are being made with both steel rollers and actual gears. The surface fatigue failures that occur on the test rollers and on gear teeth are of one and the same type. In both cases the final appearance of the pit is roughly that of a circular sector of 60 to 120 degree angle. In both cases the pit is produced by the gradual growth of a fatigue crack starting at the vertex of the future pit. Figure 2 covers a photomicrograph of a pit produced on a test roller. The mechanism and formation of pits have been a subject

FIGURE 2



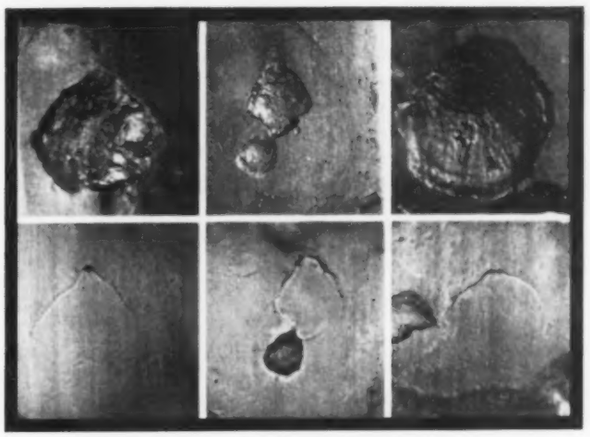


FIGURE 3

of much speculation and debate. Laboratory tests indicate that a pit results from the gradual growth of a crack that eventually separates a particle from the main body of material. The cavity thus formed is the pit. Any discussion of the cause of pitting in gear teeth must become a discussion of the cause and conditions for growth of the pitting cracks.

These cracks can be seen on the surface of the test rollers and the growth can be followed. The top view of some pitting cracks and the pits that resulted from them are shown in Figure 3. The cracks, or more properly the intersections of the cracks with the surface, are always so orientated that the part corresponding to the vertex of the V is run over first. The laboratory tests have been extended to include not only various types of materials and heat treatments but also types of oils, tooth proportions and degree of finish. Each of these has a definite bearing on load carrying capacity.

A great deal of work has also been done by the lubrication committee of the American Gear Manufacturers Association. The AGMA now have a recommended practice covering industrial gear lubrication. In this recommended practice, definite classifications of lubricant have been made and a viscosity range has been determined for each. This practice includes a list of trade names of typical oils meeting AGMA recommendations. A number of manufacturers have included this type of information in leaflets covering instructions for correct lubrication and maintenance of industrial gear drives. A number of the oil companies have also produced the recommendations which apply to their particular concern. It is expected that by continued investigation and tests, additional data will be available through the AGMA to users of industrial gear drives.

MAURICE RESWICK: Of the many problems encountered in steel mills, the lubrication of gear drives is the most fascinating. A gear reducer may be compared with an electrical transformer. Both are used for transmitting power in a modified form. The transformer usually reduces voltage and increases amperage, while the gear drive converts power delivering it at lower speed and higher pressure. In both cases we have resistance or frictional losses. In the transformer we use oil for insulation and heat dissipation, while in the gear

drive we use lubricating oil to prevent metal-to-metal contact and to carry away the heat which is unavoidably generated.

Mr. Dahlstrom's contributions on the phenomenon of wear of gears are invaluable, and in this paper he gives us a clear idea of the magnitude of sliding friction present in gear drives, and of the importance of lubrication.

Mr. Dahlstrom advances the thought that the flash point of an oil should be regarded as an important factor in the selection of a lubricant, and favors the use of heavy viscosity oils on account of their higher flash points. The actual contact of the gear teeth is usually only a fraction of a second, and we question whether or not the time is long enough to cause volatilization of the oil and rupture of the film as a consequence of the heat generated momentarily. This is particularly true in modern gear drives which are copiously sprayed with oil at the meshing line, with the mating gears acting as oil pumps.

Ideal lubrication conditions are attained when a lubricant of the lowest possible viscosity is used, which is influenced by the peripheral speed and the pressure per inch of face. With the introduction of efficient circulating oiling systems, there is now a definite tendency to use oils of lower viscosities. Lighter bodied oils generate less internal friction, circulate more readily, carry away and dissipate heat faster, and resist contamination with moisture and mill dirt to a greater degree.

The same reasoning applies to gear drives where the tooth pressures are so high that an extreme pressure lubricant must be used. Quite a number of old gear drives originally designed for lubrication with a heavy gear shield are now successfully lubricated with an extreme pressure lubricant of about 1200 seconds Saybolt viscosity at 100 degrees F. The extreme pressure ingredients in the lubricant prevent gear scoring, while the lower viscosity reduces the internal friction of the lubricant and keeps the gear drive cooler by carrying away the heat faster.

Conditions under which gear drives, even of the same design and size, are operated, vary so much that no one lubricant may be prescribed. Past experience is still the only reliable guide. Builders and users of gear drives should continue to consult the technical staffs of lubricant suppliers and keep posted on the latest developments in the oil industry.

E. W. BUCKINGHAM: The author's discussion of flash point, and its possible influence is worth considerable study, and probably has its effect on bearings under extreme conditions, as well as on gears. I would like to add one other point; that is the function of the oil as a coolant under conditions of extreme speed and heavy loads. We have a somewhat similar problem in the cutting of metals, where we think of the liquid used primarily as a coolant, and incidentally as a lubricant. With gears, under extreme conditions, we think of it primarily as a lubricant and incidentally as a coolant. In airplane design, we take into account the amount of oil flow on the gears and the amount of heat it will carry away. The cooling effect will reduce the operating temperature, etc. A mention of this incidental function of the lubricant in connection with your discussion of the probable influence of the flash point, would make the story more nearly complete.

F. P. DAHLSTROM: The discussions submitted are appreciated by the author, who feels that much value is thereby added to the paper.

Referring to the latter part of the comments by Mr. Schmitter, the theory for relative capacity of an oil was intended to apply for the scuffing phenomena.

Mr. Marthens mentions laboratory tests which are being made with steel rollers and actual gears. Since the paper was written, a paper by Dr. Way of his company has been published by AGMA giving results of these laboratory tests.

Mr. Reswick mentions that with the introduction of efficient circulating systems there is now a definite tendency to use oils of lower viscosities. If the oil from such systems is delivered to the gears in a cooler state than otherwise, the entering viscosity is thereby increased. For instance, a 20 degree drop in temperature approximately doubles the viscosity. This not only increases the film thickness but increases the temperature differential.

The remarks by Professor Buckingham furnish additional thought along these lines and are especially interesting in view of his wide consulting experience.

WARD-LEONARD CONTROL
for Strip Mill Auxiliary Drives

By E. S. Murrah and H. W. Poole

▲ EVERY steel man knows that the motors and control equipment for auxiliary drives perform functions which are as important as those of the main roll drives. Today, Ward Leonard is the accepted control for the main drives of hot and cold strip mills, and likewise, Ward Leonard control is making wide inroads into the field of auxiliary drives for these mills.

This paper analyzes the above trend and points out the advantages and economic factors which serve to justify the choice of Ward Leonard control in many cases.

Although we are all familiar with constant potential and Ward Leonard drives, it will be well to review the basic principles of each.

Constant potential drives are those which obtain power from a shop bus, or other similar fixed potential circuit, and thereby require armature accelerating contactors for acceleration to base speed. If higher speeds are necessary, shunt field weakening is required. Ward Leonard drives are those which obtain power from an adjustable potential source, the voltage of which is varied to provide acceleration, deceleration and speed control.

Motors with constant potential control are essentially constant horsepower drives throughout their rated speed range since the full load armature current remains constant and the field flux is reduced as the speed is increased. On the other hand, motors used on Ward Leonard systems are constant torque drives if the entire speed range is obtained by varying the armature voltage since the full load armature current and field flux remain constant. Obviously, when part of the speed range is obtained by armature voltage and the remainder by adjustment of the motor field, the drive is a combination of constant torque and constant horsepower.

Let us assume that we have a pinch roll drive requiring speed adjustment over a range of 4:1 on which load readings have been taken as shown in Figure 1. This load curve is typical of the majority of strip mill auxiliary drives which are essentially constant torque applications. Figure 1 also shows the same readings plotted in terms of horsepower instead of torque.

If we apply a constant horsepower, adjustable speed d-c. motor to this drive, obviously it will have to be rated 25 hp., 300/1200 rpm. in order to give the necessary torque at top speed. Curves A, Figure 1, illustrate the speed-torque and speed-horsepower characteristics of this motor. You will note that this motor has considerably more torque than necessary below top speed. This situation could be helped somewhat by applying a so-called tapered horsepower motor which would be rated 20/25 hp., 300/1200 rpm.; however, for the sake of clarity and simplicity we will stick to the original 25 hp. motor as represented by Curves A.

Since this is a constant torque drive, a Ward Leonard

Mr. Murrah (left) and Mr. Poole of the Steel Mill Section, General Electric Company, Schenectady, N. Y. presented their paper on Ward-Leonard Control at the A. I. S. E. Annual Spring Conference, Cincinnati, Ohio, April 1-2, 1940.

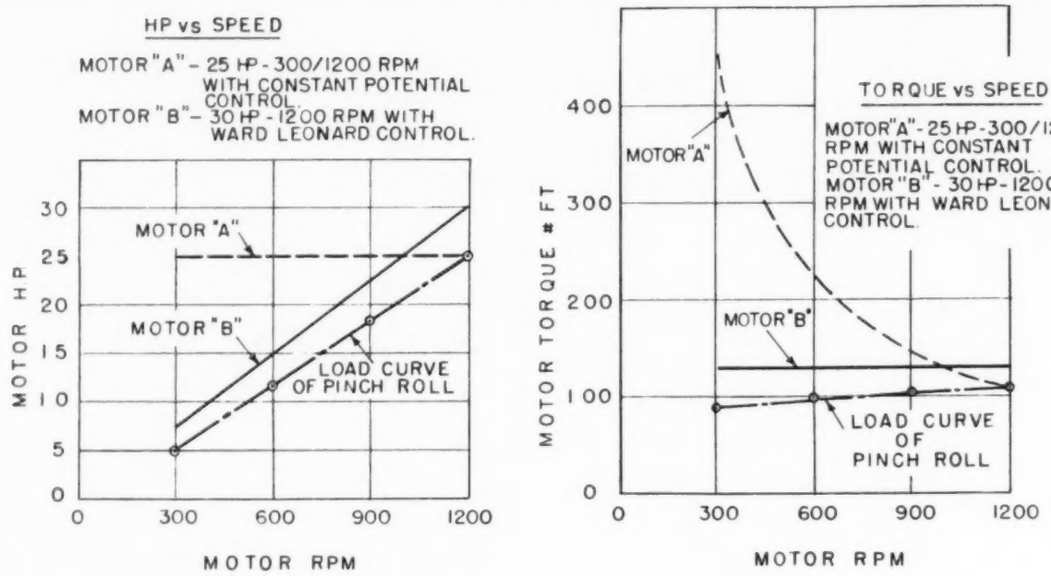

HP vs SPEED
MOTOR "A" - 25 HP - 300/1200 RPM WITH CONSTANT POTENTIAL CONTROL.
MOTOR "B" - 30 HP - 1200 RPM WITH WARD LEONARD CONTROL.
MOTOR HP
MOTOR "A"
MOTOR "B"
LOAD CURVE OF PINCH ROLL
MOTOR RPM
TORQUE vs SPEED
MOTOR "A" - 25 HP - 300/1200 RPM WITH CONSTANT POTENTIAL CONTROL.
MOTOR "B" - 30 HP - 1200 RPM WITH WARD LEONARD CONTROL.
MOTOR TORQUE # FT
MOTOR "A"
MOTOR "B"
LOAD CURVE OF PINCH ROLL
MOTOR RPM

FIGURE 1—Load curves of pinch roll drive and available hp. and torque of d-c. motor, (A) under constant potential and (B) under variable voltage.

controlled motor will more nearly meet the load requirements. However, the selection of this motor will require some particular thought. The load curves indicate that a 25 hp., 1200 rpm. motor would be suitable, but because an operating range of 4:1 is required, this motor will have to develop full rated torque continuously at 300 ft. per min.

Since an open motor depends largely upon the fan action of its rotor for ventilation and since this ventilation is reduced when the motor is operating at lower than rated speed, this should be taken into account in the selection of the motor. The curves shown in Figure 2 are representative of the loads which can be carried continuously at reduced speeds without exceeding the recommended temperature rise.

If we apply a 40 degree C. motor to this pinch roll drive, we can do one of several things. First, we can take advantage of the allowable 50 degree C. rise in which case a 25 hp. motor would be adequate. Second, we can force ventilate the motor; however, this is not usually done on auxiliary motors and we will eliminate the possibility from this discussion. Third, we can apply a motor having a slightly higher horsepower rating such as 30 hp., 1200 rpm., so that it will not be fully loaded and will not exceed its rated 40 degree C. rise at reduced speed.

In some cases the first possibility is perfectly satisfactory and is adapted; however, in order to make a fair and unbiased comparison between the constant potential and Ward Leonard controlled motors, we will handicap the Ward Leonard controlled motor to the extent of rating it 30 hp. instead of 25 hp. Curves B of Figure 1 show the speed-torque and speed-horsepower characteristics of the 30 hp., 1200 rpm. motor.

You will note that this motor fits the actual power requirements much better than the adjustable speed motor in curves A. In addition, it has several other advantages; namely, it is physically smaller and requires less space than motor A, it is less expensive than motor A, and this saving plus the saving in control equipment can be utilized to offset the cost of the motor-generator set required for Ward Leonard operation.

ADVANTAGES AND LIMITATIONS OF WARD LEONARD DRIVES

There are a number of advantages and limitations of Ward Leonard drives as compared to constant potential drives. First, we will discuss these advantages and limitations in general, and then investigate specific applications to strip mill auxiliary drives.

One of the major factors, which affects the selection of the type of control for a given application is the number of motors which must be simultaneously controlled over a certain range of speed; and the ease and flexibility with which Ward Leonard control can be applied to this problem has done much to further its widespread acceptance.

Obviously, the greater the number of motors, the more difficult is the problem, and the greater is the advantage of using the Ward Leonard system of control. It is a relatively simple matter to control the field of one generator and thereby the speeds of several motors, but the problem becomes much more complex in the case of constant potential control which requires a master rheostat for control of all motor fields simultaneously. This master rheostat consists of an indi-

vidual section for each motor field and it is exceedingly difficult from a practical standpoint to match the speeds of the various motors point by point.

In addition, adjustable speed motors on a constant potential bus are limited in most cases to speed ranges of 4 or 5 to 1, and multi-dial rheostats are limited in accuracy by manufacturing tolerances.

Since the speed regulation of the various motors will affect the success of our efforts to obtain speed control of a group of motors, it will be interesting to compare motors A and B in this respect.

It is reasonable to assume that motor B will have about the same or a little better regulation at top speed, than motor A. The regulation of motor B at ¼ normal speed will be approximately 4 times that at top speed, since the rpm. change from no load to full load remains about the same. The regulation of motor A at base speed will be better than that of B at ¼ speed since the former is operating at full voltage.

Obviously, while this example shows the general comparison, the exact figures vary with motor ratings and also with different manufacturers. In general, however, the speed regulation of the Ward Leonard controlled motor is quite satisfactory over normal operating ranges, and even over ranges of 8 or 10 to 1 as long as the relative individual motor loads do not fluctuate rapidly.

The practical speed range of an adjustable speed motor on constant potential system is 4 or 5 to 1 by field control. A single motor on a Ward Leonard generator has an infinite speed range. Where a group of motors are operated from a common Ward Leonard generator, practical speed ranges of 10 to 1 and more have been obtained. Under this condition the practical range depends upon the type of drive and the loads and ratings of the individual motors.

Obviously, the whole thing hinges upon the IR drop of the motors. If suitable boosters are provided to automatically compensate for this drop and to do so as a function of load, then the internal drop of the machines is in effect eliminated. However, due to the economics of the situation and the fact that satisfactory operation has been obtained otherwise, such a procedure has not been generally adapted for auxiliary drives.

More will be said of this later on, but for the present we will assume that all motors are operating without boosters of any sort. If all the motors are operating with the same IR drop, they can be satisfactorily operated any place from zero speed on up. On the other hand, if the internal resistances are widely different and the relative loads fluctuate widely, the practical range will be dictated by the regulation. For this reason all cases should be judged individually.

We all know that a Ward Leonard system requires only manipulation of the generator field during acceleration and deceleration, whereas the constant potential system utilizes large and expensive armature contactors which handle current peaks of 2 to 3 times their normal rating.

Fewer control devices are required with Ward Leonard control and since these are mechanically smaller and handle smaller currents, the maintenance is appreciably reduced. Furthermore, the complete control equipment will require less space than that used on a constant potential system.

It should not be overlooked in this connection that additional space is required for the motor generator set, but in many cases the set can be sandwiched in where additional length of control panel can not, or in some cases the generator can be made a part of another set.

Figure 3 shows the accelerating torque of the constant potential controlled motor A and the Ward Leonard controlled motor B.

Ward Leonard control inherently gives smooth and stepless acceleration and deceleration. This is because

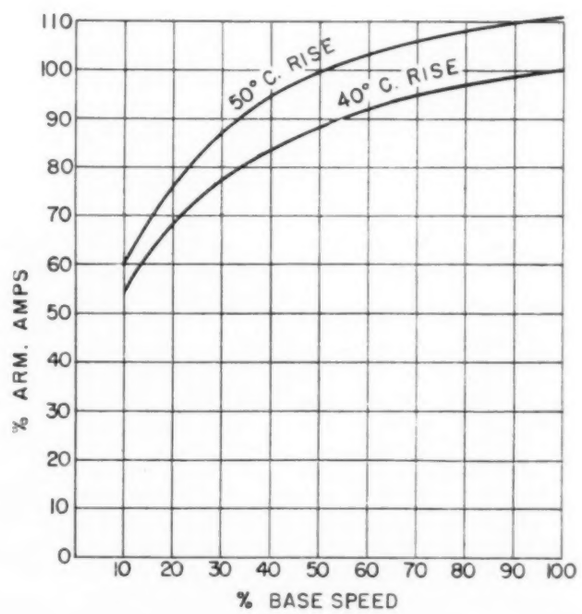
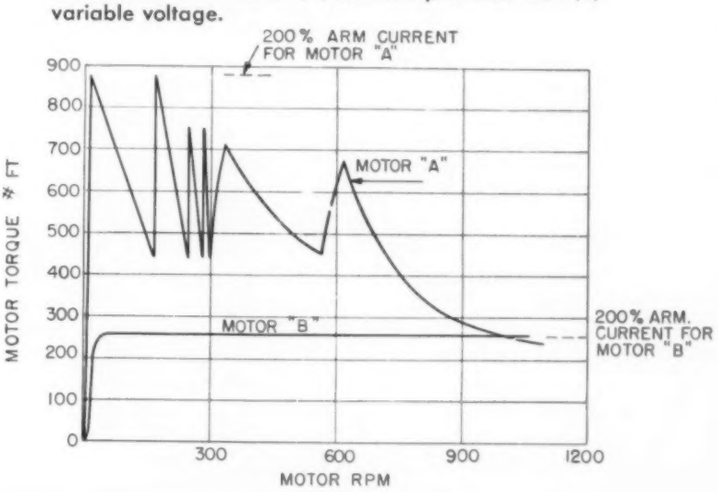


FIGURE 2 *(left)*—Current carrying capacity of d-c. motors, with full field, is reduced when speed is reduced by reducing armature voltage.

FIGURE 3 *(below)*—Curves comparing accelerating torque of motors started under (A) constant potential and (B) variable voltage.



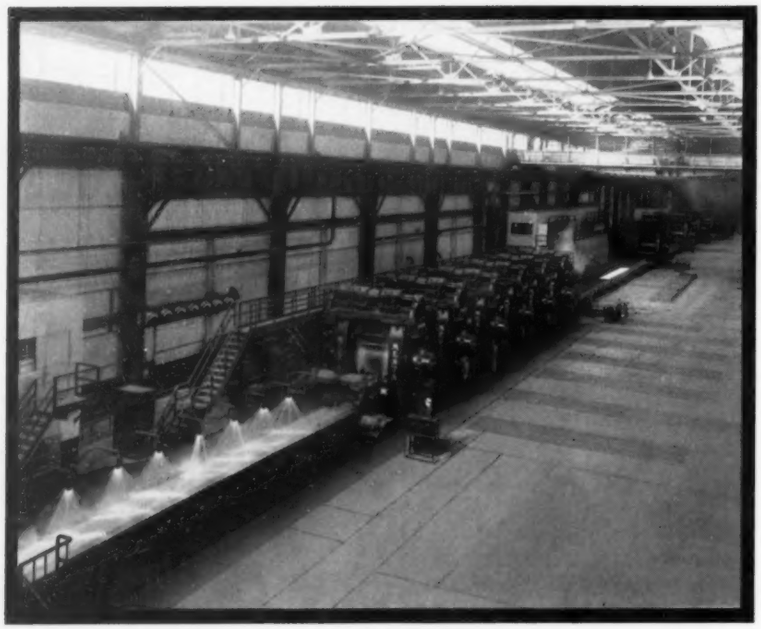
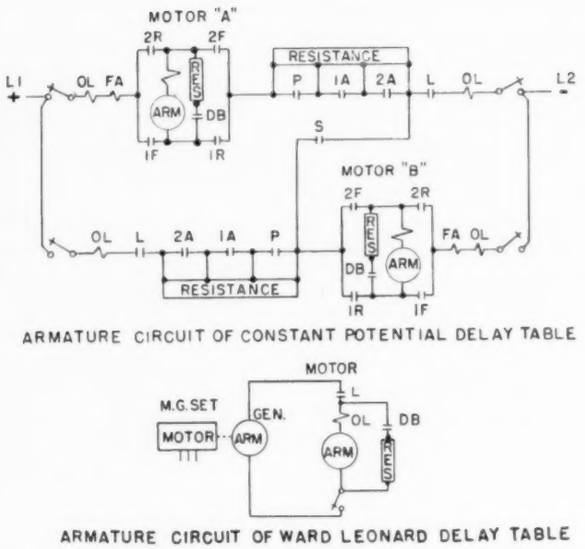


FIGURE 4—General view of finishing end of hot strip mill, showing delay table, flying shear and runout table.



ARMATURE CIRCUIT OF CONSTANT POTENTIAL DELAY TABLE

ARMATURE CIRCUIT OF WARD LEONARD DELAY TABLE

FIGURE 5—Armature circuits of d-c. motor drives for a hot strip mill requiring a 4:1 speed range.

with Ward Leonard control the accelerating torque builds up quickly but smoothly to a maximum value which can be sustained throughout the accelerating period. On the other hand with constant potential control, the torque builds up abruptly to a maximum value and then tapers off. As the armature accelerating contactors close in sequence the torque alternately forms a series of peaks and valleys. These produce jerks in the gear box and in the entire machine which are apt to cause additional wear and tear, resulting in increased maintenance and delay. This is not merely a theoretical supposition, but is a fact which has been demonstrated many times by actual experience.

Obviously the average accelerating torque of motor A is considerably higher than that of motor B. This is to be expected since motor B has less maximum torque at lower speeds and is smaller than motor A. However, if motors A and B had the same maximum rated torque, the average accelerating torque of motor B would be considerably higher than that of A.

At the first glance it may seem that the advantages of Ward Leonard operation make the equipment cost considerably more than constant potential. However, with careful selection of motor sizes, and a suitable regard for the control equipment required in each case, the Ward Leonard drive will in most cases cost only a little, if any, more than the constant potential.

There are several factors which are quite often overlooked in making a cost comparison of the two types of drives. The first is that the constant potential system should share its proportionate cost of the a-c./d-c. conversion apparatus for the shop supply. This additional cost should be figured on the basis of at least 25 to 30 dollars per kw. In addition, in those cases where the d-c. mill supply is already loaded near full capacity, it is desirable to conserve the available mill power for those drives which lend themselves particularly well to constant potential control.

Another factor to be considered is the cost of power transmission. As an example let us assume that we are installing 200 kw. of auxiliary drives, which will be located 300 ft. from the nearest a-c. or d-c. mill bus. If the cost of the 200 kw. 250 volt d-c. cable and conduit for the constant potential auxiliaries is taken as 100 per cent, the cost of the a-c. cable and conduit for the 200 kw. Ward Leonard motor generator set which is driven by a 300 hp., 440 volt a-c. motor will in many cases be as low as 60 per cent. This difference is decreased somewhat when the actual installation labor is included, but in general the 440 volt a-c. line will cost less than the 250 volt d-c. line. It is only fair to admit, however, that this situation may be reversed if the a-c. power supply is 220 volts instead of 440 volts.

Another point that should not be overlooked is that the moment Ward Leonard control is considered, we at once begin thinking of additional control functions that can be had with Ward Leonard control and which can not be obtained with constant potential control; in other words the Ward Leonard control is more flexible. Thus, these additional control functions and the flexibility of control as offered by Ward Leonard should be taken into consideration when making a fair cost comparison.

Let us make a cost comparison on the basis of the same control functions for both types of drives.

As a specific example, motors A and B may be used for such a comparison. Motor A with a suitable revers-

ing, dynamic braking control panel, field rheostat, master switch and starting and dynamic braking resistor will sell for approximately $2500. On the other hand, motor B complete with a 25 kw. motor generator set and 440 volt 60 cycle starter, Ward Leonard control, dynamic braking resistor, generator field rheostat, and master switch will sell for approximately 5 per cent less.

We must admit that this cost comparison may be reversed slightly in favor of the constant potential control if the a-c. supply is of lower voltage or 25 cycle.

A fourth factor is, that in comparing the costs of the constant potential and Ward Leonard drives, the over all cost of the complete equipment, both electrical and mechanical, should be considered since the operation of the complete installation and the return on the investment is dependent upon the flexibility and suitability of the electrical equipment.

In general, depending upon the number of motors involved, the speed range to be covered, and the torque requirements of the various drives, Ward Leonard electrical equipment may cost from 10 to 20 per cent more than constant potential. However, since Ward Leonard control lengthens the life of the mechanical equipment, the cost comparison should be made on the basis of the entire installation. When this is done, the above figures are reduced at least 50 per cent and usually more. In fact in those cases involving strictly constant torque drives and wide speed ranges, the Ward Leonard drive may be less expensive as shown in the example above.

FIGURE 6—General view of runout table of continuous hot strip mill, with individual d-c. motors on each roller.

HOT STRIP MILL AUXILIARIES

The foregoing discussion has pointed out a number of the advantages of Ward Leonard control and various factors to be considered in applying it. The next logical step is to consider its specific application to the various auxiliary drives, which in our opinion can be advantageously equipped with this control.

Starting at the furnaces and following the strip through the mill, we will first consider the slab squeezer. This particular drive is a good application for the three-field generator form of Ward Leonard control, which has proven highly satisfactory on the major auxiliaries of blooming and slabbing mills in the last few years. For details of these drives, refer to the May, 1937, and March, 1939, issues of the IRON AND STEEL ENGINEER for articles on the operation and performance of the three-field generator as applied to these auxiliary drives.

The three-field generator due to its inherent characteristics definitely limits the maximum torque to a value well within the commutating capacity of the motor. This means that if the slab squeezer is set too close, by the operator, causing the motor to stall, the current is limited to a safe value.

Usually delay tables which are located between the roughing and finishing stands of a hot strip mill are split into two independent sections, each having their respective drive motors, requiring at least 4 to 1 speed range, in order to match the delivering speed of the roughing stands and the entry speed of the finishing stands.

Figure 4 is a general view of the finishing end of a hot trip mill showing the delay tables, flying shear and runout tables.

One such recent installation has two mill type motors per each of the two table sections, each motor rated 50 hp., 550/1100 rpm., 230 volts, with series-parallel control to get 4 to 1 speed range. Thus the total horsepower per table section is 100 hp. at 550/1100 rpm.

Now let us apply Ward Leonard control to this drive, taking advantage of the ability of mill type motors to operate successfully at double voltage and speed, thus in effect doubling the horsepower rating of a given frame.

Applying a mill type motor with a nameplate rating of 50 hp., 550 rpm., 230 volts, and doubling the voltage, the rating now becomes 100 hp., 1100 rpm., 460 volts. Thus, with Ward Leonard control on this delay table, we need only one motor, while the constant potential control requires two motors. The cost of the one motor which is saved by using Ward Leonard control can go towards paying for the generator that we now need.

Figure 5 shows the armature circuit of the constant potential motors, and also the Ward Leonard motor. Note that the constant potential motors have a total of 19 armature contactors, while the Ward Leonard has only two. These figures must be multiplied by two, since there are two table sections. From a maintenance standpoint, the Ward Leonard drive has fewer control devices to service, and in addition, in case of a control

FIGURE 7—Hot strip coiler driven by five 15 hp. d-c. motors under variable voltage control.

failure, fewer devices for the trouble shooter to check.

The total price of the electrical equipment for the above mentioned constant potential delay tables we will call 100 per cent. The total price of the Ward Leonard equipment is also 100 per cent. Thus, on the basis of price alone, of the electrical equipment, the prices are comparable. But let us look at the additional advantages afforded by Ward Leonard. Instead of 4 to 1 speed range we now have, say, 10 to 1 range in speed, smooth acceleration and deceleration allowing back lash in the gearing to be taken out before the motor develops a very high value of torque, resulting in lower mechanical maintenance, and simpler control, with less devices to maintain, resulting in lower maintenance cost. It must be remembered that lower maintenance cost is always associated with fewer mill delays.

Before leaving this auxiliary drive, we might add that several steel companies have adopted Ward Leonard control to this drive and one of them, in addition, provided individual table roll motors to simplify the mechanical end of the drive also.

Crop shear drives might also warrant Ward Leonard control, giving advantages as outlined under other drives. We might add that one steel company is at present applying Ward Leonard to this auxiliary drive.

With modern hot strip mills running at 2000 ft. per min. or above, and the flying shear cutting the strip into definite preset lengths, the shear control becomes one of the toughest in the steel mill.

It is the duty of the flying shear to automatically start up from rest, and cut the strip into definite preset lengths. After the strip is through the mill, the shear comes to rest with the knives in a definite position ready for the next piece. The shear is also arranged to crop the front end only, and then must stop with the knives in a definite position, without making additional cuts. Likewise, cropping the rear end only may be performed.

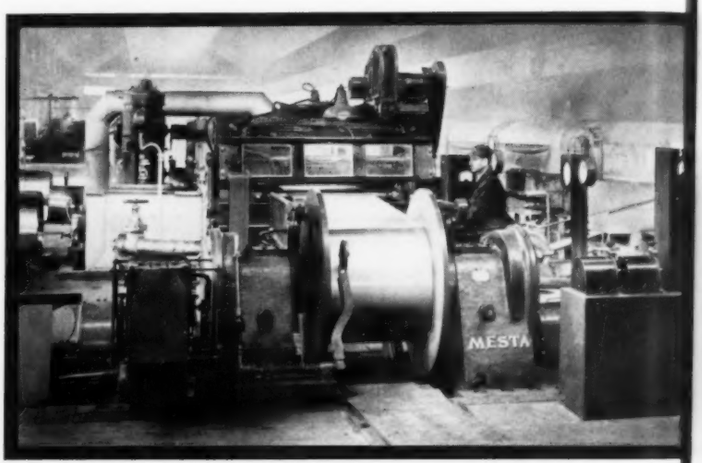
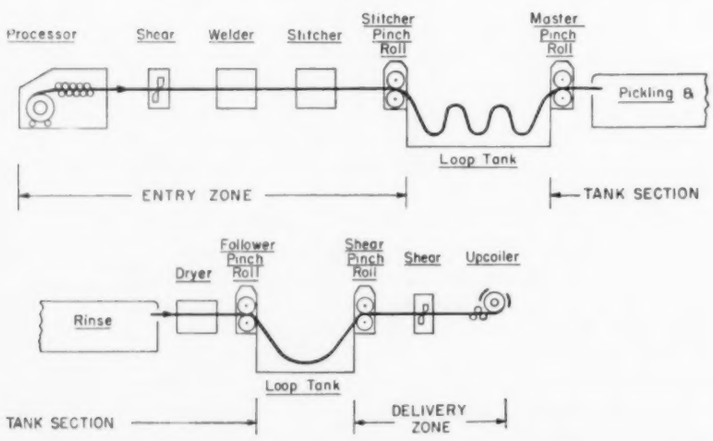


FIGURE 9—General view of entry end of electrolytic cleaning line, showing uncoiler, with welder in background.

FIGURE 8—Schematic diagram showing entry zone, tank section, and delivery zone of a continuous strip pickling line.



To accomplish all this, you can see that the shear must accelerate, and also stop in the shortest time possible.

On some flying shears where the time required to accelerate and decelerate is an important factor, higher average accelerating torque can be obtained with Ward Leonard control than with constant potential control, thus in effect cutting the accelerating and stopping time to a minimum.

Various mechanical and electrical means have been employed to keep the speed of the shear in a fixed relationship with the strip speed. This speed relationship is adjustable, and determines the length of cut. Once it is preset for a certain length of cut, any variation in this speed relationship is reflected in uneven lengths of cut.

When using a mechanical tie between the shear and the last stand, the wear and shock on this system is a

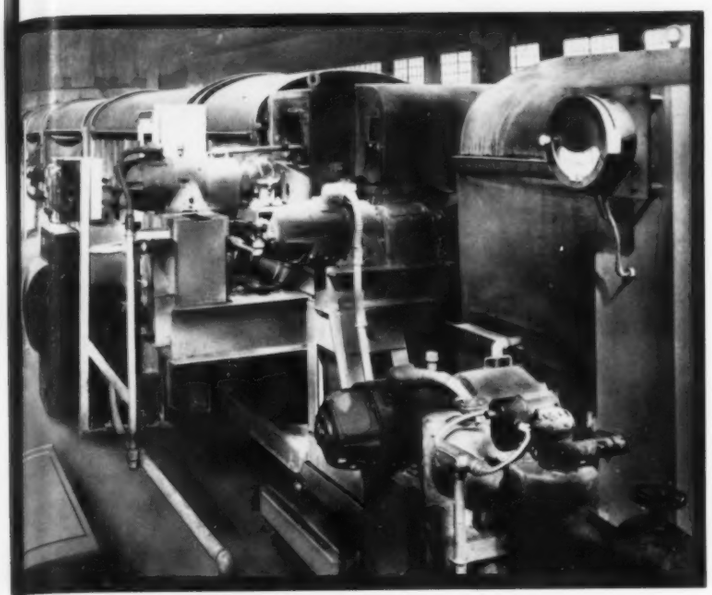
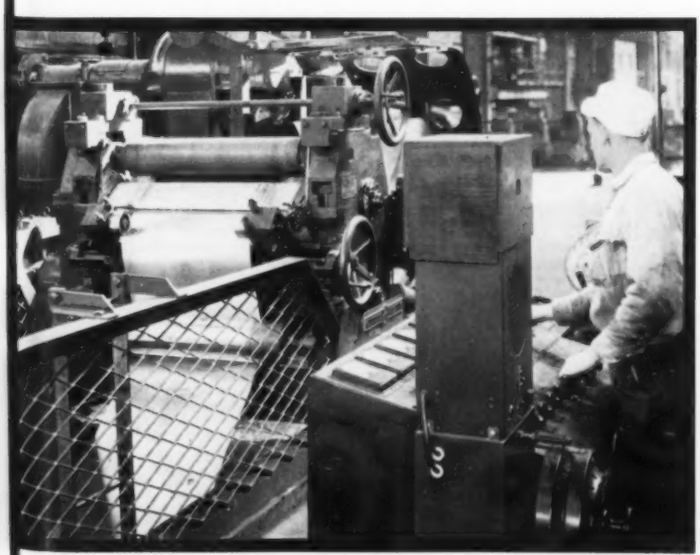


FIGURE 10—General view showing tank section of electrolytic cleaning line which is operated under variable voltage control.

major item. When constant potential control is used, a shock occurs every time the accelerating and dynamic braking contactors function. With smooth and stepless Ward Leonard control, the motor torque on starting builds up smoothly but quickly to a maximum value, allowing the back-lash in the gearing to be taken out before the motor develops a very high value of torque, thus cutting mechanical wear to a minimum.

With Ward Leonard it is possible to take advantage of the ability of mill type motors to operate successfully

FIGURE 11—Operating control desk of cleaning line is at the delivery end. Tension rolls and winding reel are shown in background.



at double voltage, thus in effect doubling the horsepower rating of a given frame. This means a physically smaller motor having less inertia to accelerate and stop than larger motors that would be required with constant potential to do the same work.

Either a speed or current regulator is required for the flying shear, depending upon whether the tie is mechanical or electrical.

If constant potential control is used, the regulator must work on the field of the motor, while with Ward Leonard the regulator would be in the field of the generator. The energy required for the generator field is less than that for the motor field. Thus, with Ward Leonard control the rate of response of the regulator is faster. Since rate of response is a very important factor to consider on flying shears, the Ward Leonard controlled shear here again offers another distinct advantage.

In the runout tables and coilers, the point is not Ward Leonard versus constant potential, but Ward Leonard versus adjustable frequency a-c. control. One only has to look at the records to see the overwhelming acceptance of Ward Leonard runout tables. All new continuous hot strip mills designed and built since 1936 have had Ward Leonard runout tables and coilers. Last year one steel company modernized their hot strip mill and changed over to Ward Leonard runout tables. Another steel company is at present doing likewise.

Figure 6 shows a general view of Ward Leonard runout tables of a hot strip mill with individual d-c. motors for each table roller. Figure 7 shows a Ward Leonard controlled hot strip coiler.

For details on Ward Leonard runout tables and coilers we refer you to the April, 1938, issue of IRON AND STEEL ENGINEER for the article "Direct Current Drives for Runout Tables and Coilers."

While the initial cost of the a-c. table drives may be sometimes less than that of the d-c. drives, it is believed that when all factors, such as power cost, demands on the a-c. system, installation expense, and flexibility, are considered, d-c. Ward Leonard drives will prove more economical.

The continuous pickling line is usually considered an auxiliary of the hot mill.

From an electrical operating standpoint, there are two main types of pickling lines in service today; that is, those which operate in two main sections with one loop or storage tank between them, and those which are divided into three sections with two loop tanks. Figure 8 shows a pickle line of the latter type.

Here in the entry zone we have a processor which flexes the strip and loosens the scale, an up-cut shear for squaring the ends, a welder or stitcher for joining the coils, a pinch roll which is used mainly for locating the tail end of the leading coil in the welder, and a loop tank which serves to make the entry zone an independent operation section.

The tank section has a master pinch roll which pulls the strip out of the loop tank and a follower pinch roll which propels the strip through the pickling and washing tanks. Here again we have a storage loop which makes the tank zone a unit operating section.

The delivery zone consists of a shear pinch roll, an up-cut shear for removing the weld, and an up-coiler. Since the maximum strip speeds are comparatively low

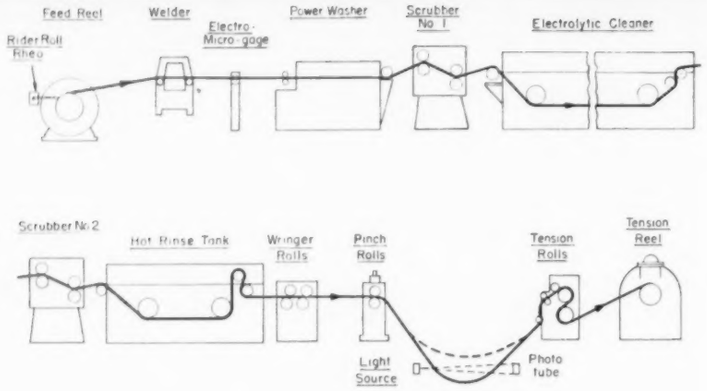
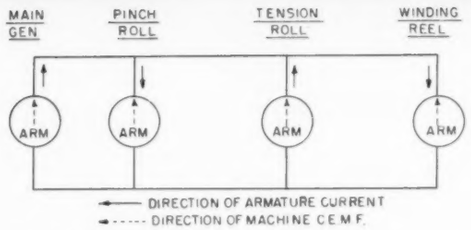


FIGURE 12—Schematic diagram of continuous electrolytic strip cleaning line, which is generally operated under variable voltage control.



GEN. VOLTS	PINCH ROLL MOTOR				TEN ROLL MOTOR				REEL MOTOR			
	I R DROP	CEMF	SPEED RPM	% RATED SPEED	I R DROP	CEMF	SPEED RPM	% RATED SPEED	I R DROP	CEMF	SPEED RPM	% RATED SPEED
230	10	220	1150	100	13	243	1300	100	20	210	400	100
200	10	190	993	86	13	213	1140	88	20	180	343	86
150	10	140	732	64	13	163	882	68	20	130	248	62
100	10	90	470	41	13	113	605	46	20	80	152	38
50	10	40	209	18	13	63	337	26	20	30	57	14

FIGURE 13—Preset speed relationship between individual motors does not remain constant when generator voltage is changed, due to IR-drop variation between motors.

(150–300 ft. per min.), the operating range less than 4:1, and since it has been necessary to synchronize only two motors at the most, there has been little need in the past for Ward Leonard control on such a line. However, new developments are continually taking place and hot and cold mills are being speeded up so that it seems certain that in the future faster methods of pickling will be used and the need will arise for a better method of electrical operation. Indeed, it is quite possible that by using electrolytic pickling which appears to be faster than the present method and in which process the pickling action takes place only as long as current is passed through the strip, the necessity of keeping the strip traveling at a uniform rate through the tanks will be eliminated and the storage loops done away with so that it will become necessary to control all motors in tandem as is now done on the cleaning lines. Of course, this will practically dictate the use of Ward Leonard control, but since fewer motors will be involved and since the motors can be chosen on the basis of the actual torque required and not just to give a speed range, the new system may be considerably more economical from an electrical standpoint than the present one.

At the present time, a new pickling line is being built with Ward Leonard control and at least one more is under consideration. They both use conventional pickling methods, but the control is 100 per cent Ward Leonard and they are undoubtedly the forerunners of many more such installations.

COLD STRIP MILL AUXILIARIES

The cold mill screwdowns, coil lifts, belt wrappers, etc., do not warrant Ward Leonard control and the cold mill reels form a part of the main drives so that these will not be discussed here. However, there are a number of cold mill auxiliaries which most certainly should be considered.

Very few constant potential cleaning lines have been installed, principally because of the need for accurate control of the recoiling process and because of the strip speeds involved.

Figures 9, 10 and 11 are photographs of the entry end, tank section, and delivery end, respectively, of an electrolytic line just recently installed. Figure 12 is a schematic drawing of this same line.

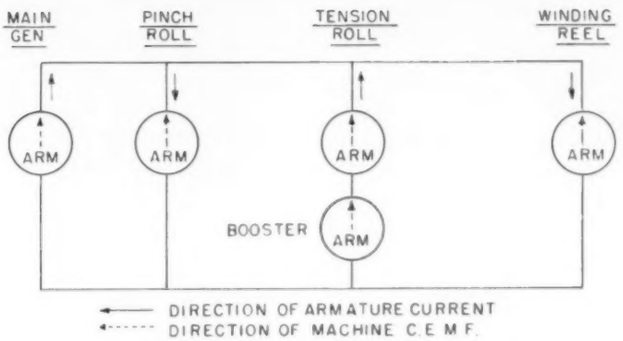
This line is one of the fastest yet installed with a rated delivery speed of 1250 ft. per min. and an anticipated speed of 1500 ft. per min.

All d-c. drives are on a Ward Leonard system with unwinding tension under the control of a rider roll rheostat and winding tension controlled by a constant current regulator. Two d-c. motors are provided on the uncoiler, one on each cone, to give controlled back tension and to be used for adjusting a new coil in the welder. The guide and back-up rollers in the cleaning tanks, washer, and scrubber units are each individually powered by small d-c. gear motors. These motors provide accelerating torque to prevent scratching of the strip and are given a slight droop by armature resistance to prevent any attempt to overhaul the strip.

The conventional loop is provided between the pinch roll and the tension rolls, with photoelectric relaying provided to control the position of the loop. Winding tension is provided by means of a drag generator geared to the tension rolls and since this is rather a common method of securing tension, it may be well to investigate this application.

In making such applications, two questions usually arise; first, what horsepower or kw. rating shall be applied, and second, what gear ratio or speed rating shall be used. Let us assume for the moment that we have a winding reel and a set of tension rolls as shown in Figure 12 with a 75 hp. motor on the reel. If we assume a mechanical efficiency of 80 per cent, then the reel motor can exert 1580 lb. winding tension in the strip. If we further assume an 80 per cent mechanical efficiency for the tension rolls, then the tension roll motor must develop 48 hp. This machine can then be powered by a 50 hp. motor or a 40 kw. generator.

If our tension roll diameter is 20½ in. and the gear ratio is 4.9:1, then the tension roll motor or generator will rotate at approximately 1150 rpm. and a 40 kw.,



GEN. VOLTS	PINCH ROLL MOTOR				TEN ROLL MOTOR					REEL MOTOR			
	I R DROP	CEMF	SPEED RPM	% RATED SPEED	BOOSTER VOLTS	I R DROP	CEMF	SPEED RPM	% RATED SPEED	I R DROP	CEMF	SPEED RPM	% RATED SPEED
230	10	220	1150	100	23	13	220	1150	100	20	210	400	100
200	10	190	993	86	23	13	190	993	86	20	180	343	86
150	10	140	732	64	23	13	140	732	64	20	130	248	62
100	10	90	470	41	23	13	90	470	41	20	80	152	38
50	10	40	209	18	23	13	40	209	18	20	30	57	14

FIGURE 14—Better speed matching is obtained at all operating voltages through IR-drop compensation by use of a booster generator in series with armature of tension roll motor.

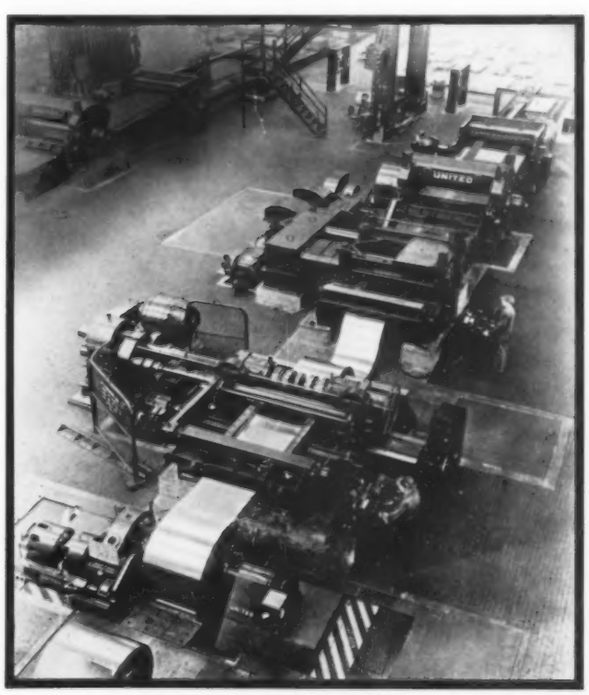
1150 rpm. generator will be satisfactory. However, if we are using a 50 hp., 1150 rpm. motor and attempt to keep the same gear ratio, we will have practically no tension in the strip—only that attributed by the mechanical friction of the tension roll machine. The obvious remedy, but one which is too often overlooked, is to increase the gear ratio or select a motor which has a lower base speed. In any event it is necessary that the strip pull the motor fast enough to raise its counter emf. above the bus voltage (230 volts) by an amount equal to the IR drop of its armature circuit. With an assumed drop of 13 volts, the gear ratio must then be approximately 5.5:1 so that the motor will be pulled at approximately 1300 rpm. and will generate 243 volts with full field.

Along this same line, some mention of the generator capacity necessary to supply the tension roll and reel motors shown in Figure 12 should be made. Obviously, since the tension roll motor returns power to the main bus in proportion to the load on the reel motor, the generator which supplies these two units need only be large enough to supply the losses of the system and to accelerate the drives. In most cases, where other drives such as pinch rolls, etc., are involved, a generator of sufficient capacity to supply these other drives plus the losses of the tension roll and reel proves quite adequate.

Where d-c. motors are applied on tandem drives and the motors supplied from a common Ward Leonard generator in such a manner that some of the machines act as motors, and some as generators, it is essential to have a true picture of the relative speeds of the machines for different generator voltages.

Figure 13 shows the generated voltages and current flow in a system which consists of a pinch roll, tension roll, and winding reel. Such a system has been applied to a number of continuous cleaning lines, and works out fairly well, but is not the ideal set-up. In order to see why, let us examine the tabulation in Figure 13 which

FIGURE 15—Variable voltage control is often warranted on side-trimming and shearing lines for sheets, as shown here.



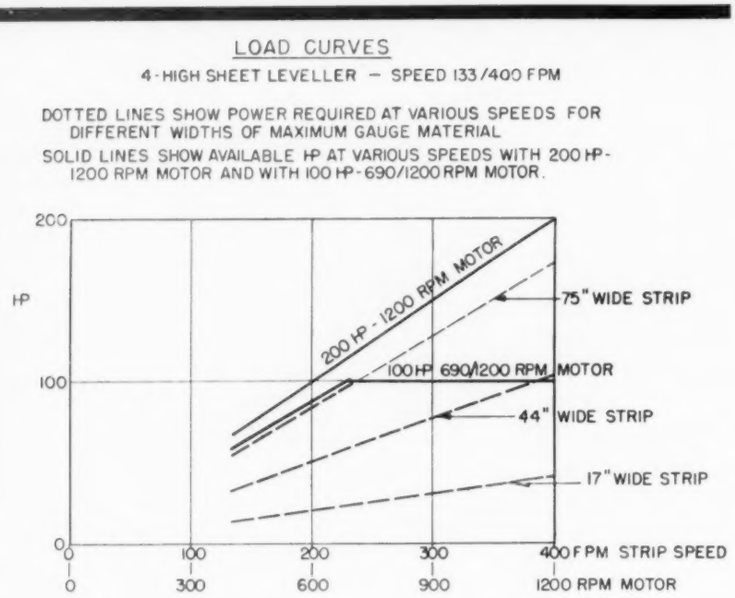


FIGURE 16—Power requirements of this sheet leveler are best met by combination variable voltage and motor field control.

gives the full load IR drop and speed of each machine.

The speed of a motor with constant excitation is proportional to its counter emf. In the case of the pinch roll and reel motors, counter emf. plus IR drop equals line voltage, and for the tension roll which acts as a generator, counter emf. minus IR drop equals line voltage; thus, the speeds do not vary directly with the impressed voltage. Obviously with such a system, even though the motor loads remain constant, there is considerable juggling of the vernier rheostats by the operator when the speed of the line is changed. This situation may be helped by placing a booster generator in the tension roll armature circuit to supply a voltage equal to the IR drop of both the pinch roll and tension roll motors so that their counter emf. are the same. This booster, in addition to providing IR drop compensation, also gives us a means of obtaining stalled tension between the drag and reel. It is now obvious from Figure 14 that the speeds match much better at all operating voltages, and that operation of the line has been improved.

Further refinements can also be made by compensating for relative load changes on the individual motors. However, since only the ease and speed of operation, and not the quality of the product, are affected this is not usually done.

In many cases, a booster is also applied in the reel motor circuit. It gives a convenient means of forcing the reel during acceleration and deceleration, and of giving the current regulator positive control of the reel motor speed when operating at low bus voltages.

In spite of the operating and maintenance advantages which are associated with Ward Leonard control of cleaning lines, the first cost compares favorably with the cost of constant potential control. A study of a recent line which was, of course, installed with Ward Leonard control indicated that adjustable speed motors and constant potential control would have cost only 2 per cent less. On the basis of the entire installation, the differential would have been less than 1 per cent. Furthermore, it would have been difficult to maintain tension during acceleration, the speed range would have been limited to 3 to 1, and the operation would have been generally inferior if constant potential control had been installed.

The next auxiliaries to be considered are the trimming and shearing lines. These lines may be divided into two

FIGURE 17—Entry end, showing uncoiler drive, of tin plate shearing line, provided with variable voltage control.

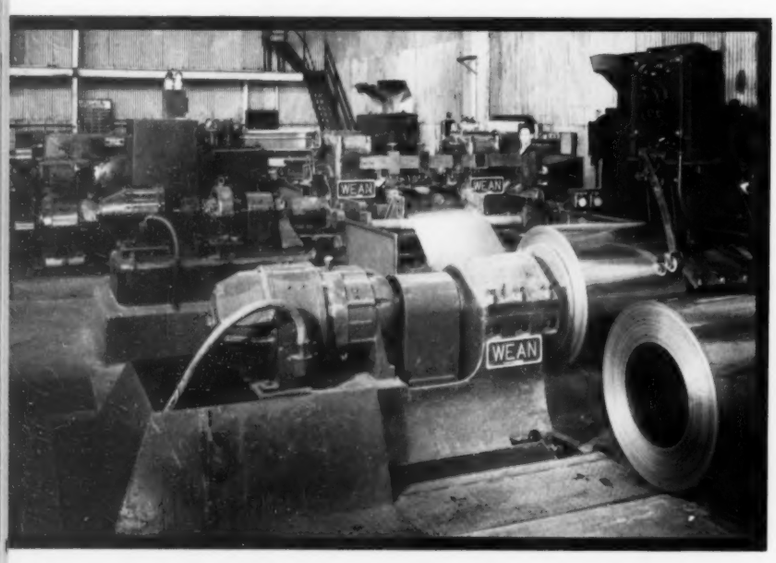


FIGURE 18—View of tin plate shearing line, showing side trimmer at left, leveler-shear in center, operators' control desk in foreground.

FIGURE 19—Delivery end of tin plate shearing line, showing sheet classifier with diverter gate for off-gauge sheets.

classes; first, those designed for sheets and second, those designed for tin plate.

A typical side trimming and shearing line for sheets is shown in Figure 15. Here we have a cone type uncoiler with an a-c. motor on each cone. Normally the side trimmer pulls the strip off of the uncoiler so that the a-c. motors are used for jogging only. The side trimmer and shear are driven by d-c. motors and must be synchronized in order to produce accurate lengths and square sheets. The conveyor and oiling machine are also driven by d-c. motors, but their speeds are not critical since they need only run at a somewhat faster speed than the shear in order to remove the sheets faster than they are sheared.

Such shearing lines run at relatively slow speeds, such as 400 to 450 rpm., have an operating range of only 3 or 4 to 1, and involve the close speed control of only two motors. As a result most installations of this type have in the past been made with constant potential control; although, wherever a shear is involved, Ward Leonard control has much to recommend it since the mechanical maintenance on the gear box can be greatly reduced by eliminating the jerks produced by the accelerating peaks of a constant potential system.

Where greatly diversified gauges and widths are handled and where such drives as levelers and shears are involved, we usually find that a combination of Ward Leonard control and adjustable speed motors is the most economical. The advantages of Ward Leonard control are thus obtained without paying an excessive premium.

Figure 16 shows a typical set of load curves for a 4-high sheet leveler. We have two choices in applying Ward Leonard control to this drive; we can apply a 200 hp., 1200 rpm. motor and cover the entire speed range by armature voltage control or we can apply a 100 hp., 690/1200 rpm. motor and obtain part of our speed range by motor field control. Obviously, the first motor will allow us to level the heaviest product at top speed, but this is not always desirable or necessary and since in the first case we need a 200 kw. generator and in the second case a 100 kw. generator, the more advantageous solution is the latter.

The tin plate shearing lines are in general operated by means of Ward Leonard control. With operating speeds of 750 ft. per min. and higher and with more motors involved than on the sheet shearing lines, constant potential control has little to recommend its use. In addition, operating ranges of 6 or 7 to 1 are quite often required in order to run off-gauge material and bad coils at slow speeds.

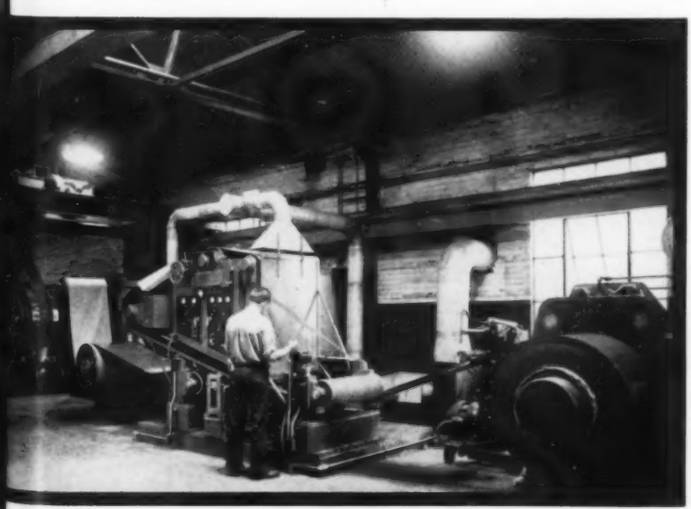
Figure 17 shows the uncoiler and side trimmer of a recently installed tin plate shearing line. Figure 18 shows the leveler shear and automatic classifier of this same line. Here it is necessary to control the uncoiler, side trimmer, leveler shear, and seven classifier motors and to accelerate and decelerate these motors simultaneously.

Obviously, it would be exceedingly difficult to maintain the necessary loops between the uncoiler, the side trimmer, and the shear during acceleration and deceleration without the precise control afforded by armature voltage adjustment. It would be even more difficult to maintain the correct speed relationship between the various classifier motors which is so necessary to the proper shingling and piling of the sheets.

In general, the same comments regarding motor selection and relative operating speeds, which were previously made, apply here. Since, in most cases, the gauge does not vary over wide limits, the main motors are usually selected on a constant torque basis and the entire speed range is covered by armature voltage with vernier field adjustment of each motor.

There are a number of auxiliary drives, such as slitting and recoiling lines, galvanizing machines, and strip polishing machines which are excellent applications for Ward Leonard control.

FIGURE 20—General view of variable voltage controlled strip grinding and polishing machine, with tension reels.



The galvanizing machines are in general best adapted to a combination of armature voltage and motor field control. This combination gives the necessary torque at all speeds without paying a premium and it allows the entire speed range of 15 or 16 to one to be covered without the necessity of changing the gear ratio between the motor and the machine.

Since uniformity and tightness of the coils are important in the slitting and recoiling process, Ward Leonard control is essential for this application. Obviously, it is very difficult and unsatisfactory to attempt to hold tension when accelerating in jumps with armature contactors and uniformity of tension at the start affects the quality of the coil which will be produced.

Strip grinding and polishing machines such as the one shown in Figure 19, require wide ranges of strip speed and tension and it is necessary for the operator to be able to jog the strip back and forth without losing tension. These two features alone necessitate a precision of control which can best be obtained by Ward Leonard operation.

DISCUSSION

PRESENTED BY

W. A. PERRY, *Superintendent of Electrical and Power Departments*, Inland Steel Company, Indiana Harbor, Indiana.

G. E. STOLTZ, *Manager*, Metal Working Section, Industrial Engineering Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

JAMES FARRINGTON, *Electrical Superintendent*, Wheeling Steel Corporation, Steubenville, Ohio.

W. A. PERRY: Ward-Leonard control has been for many years available to the electrical men in the steel mill but it has been a matter of getting enough money to put it in and in the last few years the mechanical men, realizing the great benefits that are derived from this type of control from reduced maintenance and breakage, are continually after the electrical men for another installation of that kind. It is only fair to state at this time that the electrical man immediately gets from behind the eight ball and the operating man takes his place when you have Ward-Leonard control.

G. E. STOLTZ: When electric drives were first installed in the steel industry, those for the main mill drives were taken care of by alternating current motors wherever possible, as it was felt the application was too severe for direct current motors. Where adjustable speed drives were required Kramer or Scherbius sets were used, but it was found the direct current motors on reversing equipments performed so well that steel mills began to install direct current motors, very often of the variable voltage type, on continuous running mills where adjustable speed was necessary.

Later on variable voltage equipments were used on auxiliaries and now their use on screwdowns, main tables and other main auxiliaries of large blooming mills and slabbing mills is quite common.

In recent years the further application of variable voltage has become common in processing lines such as described in this paper. The reason for this latest application is to synchronize or to maintain tension between various drives on the same line. With variable voltage equipment the apparatus can be started and stopped, regardless of whether there are two or more motors, by generator voltage and each motor will be started up at the same instant and will tend to synchronize or maintain tension whether the equipment is running full speed, accelerating, or being brought to rest. This method of drive gives far more satisfactory results than if the individual motors were controlled by rheostatic equipment.

Messrs. Murrah and Poole have given a very thorough analysis of comparative cost of variable voltage equipment with that of rheostatic control, and as a rule a new application requires such an analysis to justify the installation of variable voltage equipment. As a rule future applications are made on the superior performance of variable voltage apparatus over that of rheostatic control, and quite often the variable voltage is continued on the equipment even though its cost may be greater than that of rheostatic control.

The curve shown in the paper indicating the torque of rheostatic control as compared with variable voltage control is the real reason for better performance as obtained on these processing lines by variable voltage equipment.

JAMES FARRINGTON: I have very little to add except to say we have recently installed eight galvanizing units in which we use Ward-Leonard control, with both the motor generator sets and the control in a very tight air-conditioned house, and we have had excellent results. It is only necessary to clean the equipment once a month. Any of you who have had equipment out in the open know that that represents a considerable saving in time.

Maintenance of

AIR OPERATED TOOLS

By M. J. CONWAY, *Special Engineer*
LUKENS STEEL COMPANY
COATESVILLE, PENNA.

Presented before A.I.S.E., Philadelphia District Section, April 6, 1940.

▲ IN the use of pneumatic tools, especially chipping hammers and grinders, where these tools are used in steel mills for production work, there are several important factors affecting their operation and their maintenance:

1. Correct selection of tools for the work to be performed.
2. Effective lubrication.
3. Renewal of worn parts.
4. Complete periodic mechanical inspection of tools to determine their efficiency and when complete overhaul is necessary, and the courage to scrap and replace these tools due to high maintenance or low operating efficiency.

The correct selection of tool for the work to be performed can readily be determined by trial, and the tool of correct size and weight chosen.

Chipping hammers operate at speeds from 1800 blows per min. upwards. Lubrication is important because it minimizes the wear between the piston and barrel. The best method of lubrication is effected by the installation of a lubricator providing a constant supply of oil during the operating time of the tool and eliminating the necessity of frequently uncoupling the tool from the hose to squirt oil in through the throttle, which at best, is a poor substitute for correct lubrication. But still better than the practice of squirting oil into the barrel of the hammer through the nozzle end, which may lubricate the piston and barrel to some extent, but cannot lubricate the valve or heart of the tool. Haphazard, incomplete lubrication left entirely to the discretion of the operator is very little improvement over no lubrication at all. In many plants, operators are provided with a container of oil saturated waste into which they dip the butts and the cutting edges of the chisels, which in turn, serve to lubricate the lower end of the hammer barrel and chisel.

It is advisable to use air free from moisture, as wet air is detrimental to the tools because it first forms an emulsion with, and then gradually flushes, the oil from the wearing parts of the hammer, leaving them to operate with little or no film of oil between wearing surfaces.

In most steel plant locations where chipping hammers are used, and especially in steel foundries, a fine abrasive dust is usually encountered. Due either to the actual operating of the tool or to the operator blowing dust and scale from the work at intervals, this dust gets into the tool and, being abrasive, tends to increase wear. It also mixes with the oil in and around the tool, forming a gum which should be removed.

In order to keep air hammers in top operating condition and minimize the dust damage where it exists, it is a good plan to soak all hammers, when not in operation, in a bath of two-thirds kerosene and one-third lubricating oil, completely submerging the tool in the bath. This soaking is arranged for every night in some plants—in others only over the week-end. This tends to soften the gum and loosen any scale or foreign matter, so that when tool is again used this gum being loose, flushes out.

So much for lubrication of hammers or percussion tools. As to grinders the trend is heavily toward rotary machines. Most modern grinders have oil reservoirs or lubricators built into the tool, having a capacity sufficient for from four to eight hours' operation. These chambers should be filled morning and noon, depending on how hard the machines work. Lubricators can be used in the line if desired. However, if no lubrication is used, a few drops of oil should be put into the throttle handle to lubricate the throttle valve to prevent sticking. Lubrication in grinders is essential because the machines contain vanes or blades which bear against the inside surfaces of the cylinder and, when rotating at speeds of 4000 rpm. upward, which most of them do, the vane wear is excessive with consequent loss of power or frequent vane renewal.

Renewing of parts which wear rapidly or making so-called running repairs on hammers is advisable. Hammers are usually built with a renewable bushing or nozzle in the chisel end. These bushings should be renewed when the fit between the chisel shank and the bushing becomes loose, likewise chisels with shanks worn badly should be discarded. Decent fits between the chisel and the bushing should be maintained because in the cycle of operation of the chipper a small amount of exhaust air is shot to the front or nozzle end of the hammer, which helps to return the piston up to the valve end of the barrel to again start the cycle. If most of this shot of exhaust air is dissipated by blowing out between the worn nozzle and the worn chisel shank, the

return or upstroke of the piston is less rapid and the whole cycle of operation slows down.

Referring to grinders, the speeds of the grinder should be watched; if they run slow, it is reasonable to assume that the vanes should be checked for wear or there is dirt in the strainer. If the grinder runs too fast, it is a sign that the throttle parts are worn or need adjusting. A slow running grinder will not produce, and an overspeeded grinder is dangerous from the standpoint of wheel bursting.

Complete periodic mechanical inspection is most important from several angles. Take the chipping hammer for example: the most costly item in the operation of the chipping hammer is the wages paid to the operator; second, the cost of the air to operate the hammer; and, third, the repair cost to maintain the hammer. A hammer low in power and high in air consumption will make just as much noise and within limits hit just as fast as an efficient hammer, but the power or cutting efficiency may be down and the air consumption way up—with the result that per dollar paid out in labor and the cost of air a productive return of dollar value is far from being obtained.

A number of years ago I studied this problem with the cooperation of one of the engineers of a pneumatic tool company, and found the following to be true; namely, the average efficient life of a hammer was from two to four years, depending on type of work on which the hammer had been used and the number of shifts worked. Necessary repairs to the hammers such as new pistons, valves, throttle parts, triggers, etc., were applied from time to time due to natural wear and the hammers sent back on the job, but spot tests in the plant indicated that the hammers were gradually losing their power and operating on increased air consumption as compared to a new hammer.

We then arranged to have a representative number of these hammers sent back to the manufacturer for test to determine the following:

A. The cutting power of the hammer as compared to a new one in per cent.
B. The air consumption of the hammer as compared to a new one in per cent.
C. An estimate of cost to completely recondition the hammer. These figures were furnished to us and we were then in a position to determine whether to have the hammer reconditioned or scrapped (taking into consideration the time the hammer had been working; *i. e.*, number of months).

We finally arrived at the following: If the efficiency was more than 20 per cent down or the air consumption 20 per cent high, the hammer was considered for complete overhaul or scrapping. We then took into consideration the cost to repair the hammer, and if in conjunction with the low efficiency and high air consumption this cost ran 30 per cent or over, the hammer was scrapped and new ones purchased. We found that it did not pay to spend too much money per hammer for reconditioning, because while the valve and box could be renewed, barrel and handle be completely reconditioned, it was impossible to relieve the fatigue set up in the threads of the barrel and the handle where they screw onto each other, this fatigue being a result of the constant vibration of the piston impacting on the chisel. The result of all this was that, after the reconditioning expense and the hammers having been put back on the job, the threads would upset, strip, or the barrel or handle would crack through the threads, and the hammer then became useless.

The same thing applied to grinders when they gradually slowed down, became weak in power and high in air consumption. We followed the same procedure of having them tested and obtaining an estimate of complete overhaul. The grinders did not represent as serious a problem because we could roughly judge by the volume of sparks thrown what condition the grinder was in, whereas with a chipping hammer we would have had to weigh the chips or measure the length of cuts. We believe that by having the tools inspected periodically by competent mechanics it is not difficult to judge when a complete test and estimate should be made with the resultant replacement of tools from time to time. We have found in this manner we obtain good dollar life from the tools by obtaining a high productive return from them —our air costs are maintained at a minimum and repair costs at a reasonable figure.

Thought should also be given to the placing of the work for chipping or grinding in order that the working posture of the operator be as close to comfortable as possible. This together with keeping the tools in good operating condition will insure peak production on an otherwise unpleasant job.

DISCUSSION

PRESENTED BY

N. C. BYE, *Chief Engineer,* Henry Disston and Sons, Inc., Philadelphia, Pennsylvania.

M. J. CONWAY, *Special Engineer,* Lukens Steel Company, Coatesville, Pennsylvania.

L. V. BLACK, *Electrical Superintendent,* Bethlehem Steel Company, Bethlehem, Pennsylvania.

J. C. REED, *Electrical Engineer,* Bethlehem Steel Company, Steelton, Pennsylvania.

N. C. BYE: Mr. Conway stated that the life of the chipping hammer was two to four years. Is that on single shift operation?

M. J. CONWAY: Yes, single shift operation, two to four years, and depending, of course, on the type of material chipped.

N. C. BYE: Do you carry through from one hammer operator to another—that is, are the hammers interchangeable between operators?

M. J. CONWAY: Interchangeable between operators, yes.

L. V. BLACK: I would like to ask Mr. Conway whether he has made any test on the efficiency of the hammers, depending on air pressure—if the air pressure falls ten per cent, what effect would it have on the operation of the hammer?

I might state in connection with Mr. Bye's question that at Bethlehem we originally used the same hammers

all day, dispensing them to the chippers on each shift, working three shifts per day. We conceived the idea that if each man would have his individual hammer, the success of chipping might be greatly improved, whereby we secured a number of hammers and gave each man his own hammer, making him responsible for the hammer and having him return it to the tool-room at the end of each shift.

From the calculations that were made, I believe the life of the hammers increased about 30 per cent by having each individual man use his own hammer.

M. J. CONWAY: Answering Mr. Black on the efficiency of the hammer, if the air pressure drops 10 per cent, what happens? The number of rpm. or the number of blows struck per minute decreases; hence the efficiency drops down, and as you are trying to produce a certain given poundage of chips per unit of time, and if the efficiency of the hammer drops, say 20 per cent, due to air pressure drop and the operator is receiving 80 cents an hour, average, you are losing 16 cents an hour on the operator, and it is easy to lose the cost of a new hammer in a short time, due to this lost efficiency. Yet, apparently, the operator is working just as hard as the man next to him who may be working with an efficient hammer. So, primarily, the efficiency of the operator is up to the hammer.

J. C. REED: I would like to know how you ascertain the amount of air the hammer uses—that is, how you measure it.

M. J. CONWAY: There are meters that will measure the amount of air a tool will use. It is possible to purchase a compressed air meter to measure the air going to the average hammer. It costs about $40.00 or $50.00. I know of one New Jersey manufacturer who makes such meters.

J. C. REED: Are they practical?

M. J. CONWAY: Yes, they are practical.

G. C. PFEFFER: How would you identify the various hammers—do you have tags or numbers on them?

M. J. CONWAY: Each of our hammers has a number stamped on it.

Rehabilitation of ELECTRIC FURNACE EQUIPMENT

By G. O. VAN ARTSDALEN, *Superintendent of Maintenance*
HENRY DISSTON & SONS, INC.
PHILADELPHIA, PENNA.

Presented before A.I.S.E., Philadelphia District Section, April 6, 1940.

▲ THIS short discourse is given to portray factors encountered in both reconditioning and modernizing electric furnace equipment that was installed nineteen years ago. Improvements were added from time to time as they were proven to be beneficial toward improving melting practice, speeding up production and reducing power disturbances.

The six-ton furnace in question was of the latest design in 1921, but its shortcomings were numerous. Its three electrodes were controlled by tapped contact-making ammeters which controlled the start, stop, and reversal of single speed electrode motors through slow acting intermediate relays. The coils of the contact making ammeters contained eleven taps varied by a dial switch, and the power input to the furnace was varied in eleven definite steps which at times seemed to be a small fraction of the number actually needed. The electrode motors themselves, having but one speed, lowered the electrodes as rapidly as they raised them, so that when melting heavy scrap of high conductivity, tremendous current surges were created and great difficulty was experienced in keeping the transformer oil circuit breaker closed during the melt-down period.

The 1500 kva. transformer supplying power to the furnace was of the single secondary voltage, low reactance type which in no way reduced the troubles caused by poor electrode control.

After operating for several years with the above mentioned equipment the necessity was felt for increasing the melting capacity by purchasing new melting equipment or speeding up the production of the existing equipment to take care of the increased needs. A three-ton furnace was also operated with controls of the same type as the six-ton furnace, following the same general furnace practice.

After a careful study of the two methods proposed to step up production, the decision was made to modernize existing equipment.

The three-ton furnace was originally supplied with power from a 750 kva. transformer which also created a limitation to melt down speed. This transformer was

of the oil-insulated self-cooled type and any attempt to shorten melting time reflected immediately on the transformer temperatures which in spite of added air-blast and oil circulators persisted in remaining in the vicinity of 70 degrees C. most of the time.

The 1500 kva. water-cooled transformer originally installed for the six-ton furnace was, with the new set-up, used to replace the 750 kva. transformer then at the three-ton furnace. This three-ton furnace, due to its small size, could produce to expectations with but one secondary voltage and, with the addition of an external 10 per cent reactance, a two speed electrode motor control panel and a solenoid operated oil circuit breaker, the three-ton furnace was found to be able to produce approximately 20 per cent more tonnage than before.

A 2500 kva. oil insulated, water cooled transformer was purchased for the six-ton furnace which was of a greatly increased reactance over the 1500 kva. transformer and had the additional possibility of being set up for three different voltages at a time to be selected at will from the control panel. Tap changing oil circuit breakers were also installed at this time as well as the necessary voltage selector panel and the then most modern type of electrode control. Due to the fact that the transformer primary winding would be materially shortened to obtain the highest secondary voltage, a 10 per cent reactor was also found necessary and installed. This reactor was also tapped and the circuit so designed to connect sections of the reactor in and out as the transformer output voltage was changed. The electrode control panel was equipped with high speed contactors and arranged to give three times the speed when raising the electrodes as when lowering them. The speeds selected prevailed when the electrodes were controlled automatically by the contact making ammeters but an additional increase of speed was arranged to function only when the electrodes were controlled manually with the line oil circuit breaker open, to facilitate setting the furnace for charging or for moving the electrodes more quickly at any time with the power off the furnace. The new contact-making ammeters contained untapped coils which were shunted with a rheostat having 50 steps and making possible a much greater variation in power input than with the original tapped coil type.

After the new equipment was installed the two furnaces were operated with a proven added capacity of 25 per cent in tonnage output, to be attributed directly to the above mentioned improvement in addition to some minor mechanical changes and minor changes to the original furnace melting practice.

In 1932, use of the six-ton furnace was temporarily discontinued and melting needs were taken care of with the three-ton furnace. The equipment was cared for to some extent during the shut-down period but when it was decided to again put it in operation, a complete overhauling was felt necessary.

The transformer, not having been energized at all during the shut-down, was the most doubtful as to condition and work was started there first. Megger tests showed a satisfactory insulation condition but oil samples tested showed the presence of plenty of moisture. About 150 gallons of oil were drawn off at the bottom of the tank, being passed through a combination centrifuge and blotter press, then stored in clean drums. The balance of the 960 gallons of oil then was found to be in fair enough condition to be reclaimed by continued circulation through the blotter centrifuge. This oil was pumped from the bottom of the tank, preheated to 60 degrees C. at the centrifuge, passed through the centrifuge and blotter press and then returned to the top of the transformer tank. This work was carried on without interruption, twenty-four hours a day, for five days after which considerable improvement in the condition of the oil was in evidence. Dielectric tests showed the average from seven test cups to hold at 25,000 volts between two one-inch parallel discs one-tenth of an inch apart. At this time the 150 gallons of oil first removed from the transformer were completely passed through the machine with the centrifuge set up for dehydration. The blotters in the press were changed more frequently and in a comparatively short time this formerly very wet oil was completely reclaimed, giving the same results on test as did the main body of the oil. During the entire oil reclamation process, the primary windings of the transformer were connected in series and energized from a direct current source, the value of current being kept the same as the normal full load current of the winding. The bulb of a recording thermometer was inserted temporarily next to the core at a point assumed to be the hottest spot and current was regulated to maintain a temperature of between 65 and 70 degrees C. all of the time. The heat supplied thus by the winding itself has always been found to be the best method of completely excluding moisture from any transformer that has been idle for a long period of time. The transformer was energized with direct current continuously for the entire time that work was under way on other sections of the six-ton furnace equipment. No water was supplied to the cooling coils so that it was an easy matter to maintain higher than operating temperatures during the drying out period. When sufficient drying had been done the current was reduced in very gradual steps to reduce the temperature slowly, thus preventing breathing into the tank any moisture that might enter with a sudden drop in temperature. Before the cooling water was turned on into the transformer pipe coils compressed air at 65 lb. pressure was applied with the discharge ends of the coils capped. Careful watch was maintained in the transformer for air bubbles in the oil, and air pressure gauges watched closely to definitely ascertain the presence or absence of leaks. Water was then applied and permitted to circulate. This transformer cooling water, after leaving the transformer, serves as the cooling medium for the electrode holders and roof coolers, discharging finally into a visible drain so that the flow can be watched at all times.

A recording thermometer was permanently installed with its sensitive bulb inside the transformer case, the instrument itself being mounted at the control panel where it is readily possible for the furnace operator to read transformer temperatures easily. An alarm is connected to this thermometer to sound a gong when the transformer temperature reaches 65 degrees C. Normally the transformer temperature does not exceed 55 degrees C. even in summer, but as one-half hour's operation without circulating water during the melt-down period would send the transformer temperature skyrocketing, the alarm is felt to be very essential.

The four oil circuit breakers connected in the six-ton furnace wiring system were next in line for overhauling.

Beside the usual oil circuit breaker maintenance, these switches required complete dismantling to treat corroded moving parts not to be reached otherwise. Porcelain bushings were secured, copper studs and contact blades and tips were wire-brushed to remove accumulated oxides and in some cases complete linings of the oil tanks that had been made of plywood had to be renewed. Mechanical moving parts of the solenoids and their attachments were wire-brushed, brightened and lubricated and, after complete reassembly, the usual routine of adjustment for contact pressure and alignment was gone through. Auxiliary devices and contacts were cleaned and adjusted for correct operation.

The instrument panel required little attention other than external cleaning and painting as the removal of instrument cases showed a remarkable absence of dirt, and all movements were rendered operative with but minor adjustments.

The electrode control relays, being of the rocker type, needed no dismantling for hinge pin maintenance as the original relays would have done. A general cleaning and renewing of arcing tips rendered these relays as good as new.

The contact making ammeters did not fare so well. Their motion takes place on hardened steel bearing pins which, not being corrosion resistant, were found to be badly pitted and in most instances required renewing. The special alloy contact tips were carefully dressed and matched. The oil dash pots were dismantled and cleaned thoroughly, after which they were reassembled and filled with new oil.

The electrode motors themselves were removed and completely disassembled. Little cleaning was required but a thorough test was made of armature and field coils, some requiring baking to drive out moisture that had accumulated during a long period of inactivity. During the process of motor overhauling, the worm driven electrode lifting mechanisms were disassembled, cleaned, supplied with fresh oil and reassembled. Except for one ball bearing replacement no new parts were needed.

Heavy secondary busses and flexible connections from the power transformer to the furnace electrodes were carefully checked and one joint that had been found loose was pulled apart, cleaned thoroughly and reassembled.

Little mechanical overhauling was necessary aside from the cleaning of moving parts, flushing out of bearings and renewing the oil in them. Certain changes were made to charging door operators, door frames and arches as well as the rearrangement of platform layout and ladle handling equipment. Flexible connections in the water system were renewed and most piping was cleaned with compressed air before finally being put into operation.

When power was applied to the furnace for the first time, no difficulty was experienced with the exception of tripping relay adjustments and an occasional adjustment of electrode motor speeds. The initial heat was tapped on schedule as has each succeeding heat, with no time lost whatsoever due to mechanical or electrical failure during the first five months of operation.

DISCUSSION

PRESENTED BY

L. V. BLACK, *Electrical Superintendent*, Bethlehem Steel Company, Bethlehem, Pennsylvania.

L. V. BLACK: I was very much interested in Mr. Van Artsdalen's paper; he brought out many points which I am sure will be helpful to us.

The light and horn alarm mentioned in the paper, which is used as a signal to warn the operator of transformer heating, or pump failures, has a very important duty; its failure to give an alarm may result in the loss of very expensive equipment. At Bethlehem, in addition to the light and horn alarm used as a signal for overheating of the transformer, or failure of the water pump and the oil pump, all control circuits are interlocked so that any failure of pumps or overheating of the transformer, will cause the main power circuit breaker to the furnace to be tripped, thereby insuring the equipment against the possibility of operating at dangerous temperatures.

A very interesting test was made a few days ago in connection with Bethlehem's 25-ton arc furnace, which was quite enlightening to us and corroborates one of the points brought out in this paper—that of increased production due to modernizing the furnace and changing the percentage of reactance used.

The 25-ton furnace operates directly on the plant 6600 volt, 25 cycle system. The furnace transformer is 6250 kva., delivering 13,000 kw. during the melt-down period. Overheating or high transformer temperatures are not experienced, due simply to the installation of an oil cooler of double the capacity normally used for a transformer of this rating.

During the test, the furnace was disconnected from the plant system and connected directly to the power company's system. The test was doubly interesting in so far as it is commonly known that all utility companies consider arc furnace loads as the least preferable, causing wide variations in voltage, especially during the melt-down period.

The power company carried the arc furnace as load on the end of a radial feeder some 20 miles from the source of generation—the open circuit voltage at the furnace was 7000 volts. During the melt-down period, the primary voltage dropped to 5900 volts—melting was started on the 114 volt tap, gradually increasing the voltage until after one-half hour's operation, the load steadied at 7000 kw. on the 154 volt tap. Primary voltage varied from 6200 to 6300 volts. An attempt was made to operate at 8000 kw., but at that rate the charge could not absorb all the heat, and the energy was reduced to prevent furnace side wall and roof damage.

An interesting feature noted was that no upward power surges were encountered, all variations in load were toward the zero side of the chart. Another point of interest was that the load curve was much more steady than on any previous heat, when operated on our own system. The added reactance in the line from the power company's power house to our plant, was no doubt the answer. A 15 per cent reactor is used in connection with the furnace transformer.

The more steady flow of power under the test conditions cut one-half hour off the time for the heat—practically all this time saved was during the melt-down period.

Power Generation Expansion

AT BETHLEHEM'S LEBANON PLANT

By H. U. Johns

Mechanical Engineer

BETHLEHEM STEEL COMPANY

LEBANON, PENNSYLVANIA

Presented before A.I.S.E., Philadelphia District Section, April 6, 1940.

▲ THE need for additional power at the Lebanon plant of the Bethlehem Steel Company made desirable a study of the methods most suited to increase the capacity and efficiency of the existing plant. This plant was originally built in 1914 with additions in 1919, 1929, and 1937.

The steam generating plant consists of ten boilers, each of 520 boiler hp. rating, with six of the boilers burning pulverized bituminous coal, two burning slack bituminous coal on stokers, and two burning No. 3 anthracite buckwheat coal on chain grate stokers. The turbo-generator equipment consists of condensing units, one each of 2500, 5000, 7500, and 10,000 kw. capacity. Power is generated at 2400 volts, 3 phase, 25 cycles, with step up transformers to increase voltage to 11,000 volts to supply power to the Cornwall mines and the concentrator plant. The larger units at the local plant operate at 2300 volts while the small motors are 440 volt. The limiting load on the existing plant is 16,000 kw. with short peaks reaching 17,000 kw. One of the limiting features is the supply of condensing water which is very low during dry seasons. For this reason it was not desirable to increase the load on the condensing turbines. The present steam generating plant has also reached the limit in capacity so that any increase in power needs would necessitate additional boiler capacity.

The final decision on the design of the new plant was to install a high pressure steam generating unit with a high pressure turbine exhausting into the present low pressure main, the high pressure to be 650 lb. gauge, 750 degrees F. total temperature at the turbine with an exhaust pressure of 155 lb. gauge and approximately 500 degrees F. total temperature, the boiler capacity to be 150,000 lb. per hr. with 650 lb. pressure and 750 degrees F. at the superheater outlet. Fuel selected was fine anthracite because the plant is located about 35 mi. from the anthracite region, with plenty of small sizes available. It was also decided to use this fuel in pulverized form.

The choice of the higher pressure and temperature steam boiler, superimposed turbine generator, and use of pulverized anthracite coal for the new station was based on comparison of operating results of plants running similar equipment under similar load conditions, and, on calculations of efficiency and economy of such plants. Comparison of the data thus obtained with performance figures of the present low pressure steam plant indicated that the right course lay in installing one boiler having a capacity of 150,000 lb. steam per hr. and one turbine generator of 3000 kw. rating, exhausting steam at 155 lb. pressure and 500 degree F. temperature into existing 150 lb. pressure 10,000 kw. and 5000 kw. turbine generators. The comparison of and discussion on the limiting conditions also indicated that good economy would be obtained by adopting a steam pressure of 650 lb. gauge, with total temperature of 750 degrees F.

The high pressure turbine will use 100,000 lb. steam per hr. at full load. Since the high pressure boiler will generate 150,000 lb. steam per hr., 50,000 lb. per hr. of this steam will be reduced to 155 lb. pressure and 500 degrees F. temperature for use in the low pressure turbines.

The total low pressure steam available from the high pressure turbine exhaust and the surplus steam from the high pressure boiler, will be 154,000 lb. per hr. at 155 lb. pressure and 500 degrees F. temperature.

The production of electric power by these units and their efficiency and economy may be as shown in Table I. Electric power requirement in the near future will be 94,000,000 kw. hr. per yr. This power load and the corresponding steam production will be distributed as given in Table I for the hourly load of 18,000 kw.

The high pressure boiler will produce steam for generating 10,700 kw. The balance of 7300 kw. will be produced on steam from present 150 lb. boilers. Of the latter, the stoker fired units will be run to their limit of 200 per cent of rating. The balance of the lower pressure steam load and peaks will be carried on two boilers fired with pulverized bituminous coal.

The operating cost of the plants may be as shown in Table II.

It may be of interest to compare the probable cost of steam produced on No. 4 buckwheat anthracite coal burned on chain grate stokers with the same coal burned in the pulverized form, 85 per cent through 200 mesh screen. Our practice and data from other plants indicate

TABLE I

Boiler	Turbo generator	kw.	Water rate	Lb. steam per hr.	Cost per 1000 lb. steam
650 lb.—750 degrees F. steam temperature	Topping turbo generator—650 lb. steam	3000	33.3	100,000	$0.19
150,000 lb. steam per hr.	On 150 lb. exhaust steam from topping unit. Used in 5000 and 10,000 kw. 150 lb. units.	5000	20	.....	.....
50,000 lb. at 650 lb., 750 degrees = 54,000 lb. at 150 lb., 500 degrees F.	On 50,000 lb. surplus steam from 650 lb. reduced to 150 lb., 500 degrees F. Used in 5000 and 10,000 kw. units.	2700	20	54,000	.....
Two 500 hp., 150 lb., 500 degrees F., anthracite coal stokers	On 150 lb. steam, in 5000 and 10,000 kw. units.	3200	20	64,000	$0.23
Two 500 hp., 150 lb., 500 degrees F., powdered bituminous coal.	On 150 lb. steam, in 5000 and 10,000 kw. units.	4100	20	82,000	$0.31

that the heat balance and cost shown on Table III may be expected.

The coal as fired contains 69 per cent carbon, 2.5 per cent hydrogen, 0.7 per cent sulphur, 12 per cent ash, and 11 per cent moisture. The net heat value is 11,400 Btu. per lb.

Exit flue gas temperature 450 degrees F.; CO_2 in wet flue gas 14 per cent; temperature of feed water to economizer 220 degrees F.

The difference in expected operating cost of the two methods of burning small size anthracite coal is due to 5 per cent higher fuel efficiency and 25 per cent lower cost above fuel, in favor of pulverized coal. The figures given in the heat balances above seem to us to be fair to each type of equipment.

The new power plant building is of structural steel design with brick walls, steel sash and doors, and concrete tile roof with insulation and asbestos felt roofing. The building is 84 ft. by 68 ft., and 70 ft. high with an additional 9 ft. over the coal bunker. Ground floor and operating floor are of reinforced concrete and platforms and stairways are covered with steel grating.

The new high pressure steam generating unit is of the three drum type bent tube boiler having 12,500 sq. ft. of heating surface. The boiler is designed for a maximum working pressure of 725 lb. per sq. in. and will be operated at a pressure of 660 lb. gauge at the superheater outlet. The two upper drums are 42 in. and 54 in. diameter and the lower drum is 42 in. diameter. The boiler tubes are arranged in three banks. The first bank has 3 in. diameter tubes and the other banks have 2 in. diameter tubes. The superheater is of the four loop pendent type and consists of 2 in. diameter bare tubes arranged vertically and supported from headers above the boiler setting. The superheater is located between the first and second bank of boiler tubes.

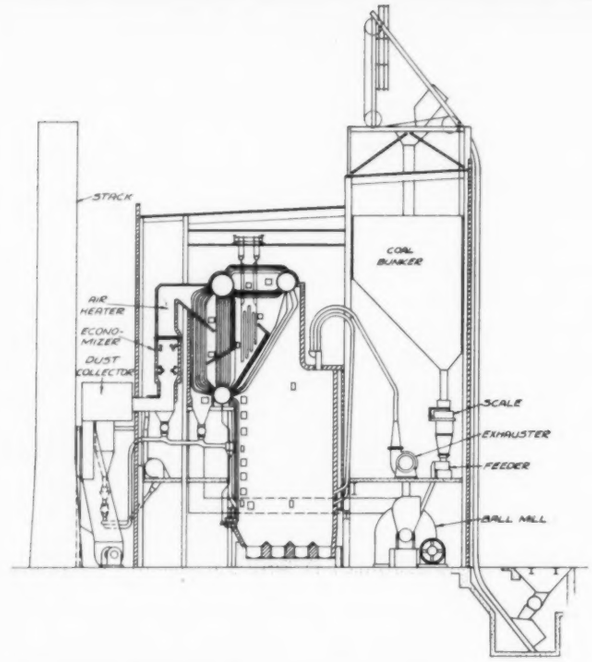
The combustion space is of ample size to give complete combustion before the gas hits the first bank of tubes, being approximately 19 ft. square by 30 ft. high. The design of the combustion chamber includes a flat arch to provide a horizontal surface for installation of the pulverized anthracite burners. The front and two

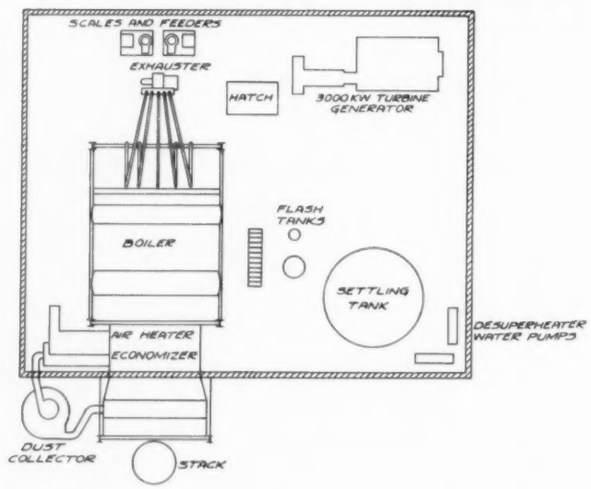
TABLE II

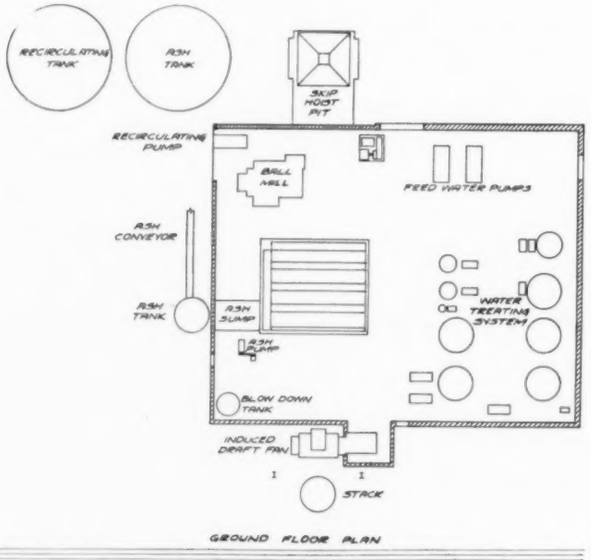
	Kw. produced per hr.	Lb. steam per hr.	cost of steam per hr.	Total cost of electric power per 1000 kw. hr. Steam = 85 per cent of total cost
650 lb. boiler, 3000 kw. high pressure and 150 lb. pressure units from 650 lb. boiler.	10,700	150,000	$28.50	$3.36
150 lb. anthracite, stoker fired, and bituminous powdered coal fired boilers.	7,300	146,000	$40.88	$6.59

TABLE III
BOILER HEAT BALANCE
(Percentage)

	Chain grate stoker	*Pulverized coal*
Heat loss in wet flue gas	11.1	11.6
Heat loss in burning hydrogen	2.3	2.3
Heat loss in carbon in ashes and soot	8.0	3.0
Heat loss in radiation, etc.	4.6	4.1
Sum of heat losses	26.0	21.0
Efficiency of unit	74.0	79.0
Steam pressure and temperature	650 lb. gauge 750 degrees F.	650 lb. gauge 750 degrees F.
Cost of fuel per 1000 lb. steam	$.1145	$ .1215
In total cost of steam, fuel equals	55 per cent	64 per cent
Total cost per 1000 lb. steam	$.208	$ .191
Saving in cost on 150,000 lb. steam per hr.	....	$2.55
Saving per year of 7000 hr. (80 per cent of total time)	....	$17,850







GROUND FLOOR PLAN

FIGURE 1 *(top)*—Sectional view through boiler, showing auxiliaries.

FIGURE 2 *(middle)*—Plan view of the operating floor.

FIGURE 3 *(bottom)*—Plan view of ground floor.

side walls of the combustion chamber are air-cooled refractory tile construction with insulation while the lower rear wall below the lower drum is water cooled by 3 in. diameter bare tubes which form an integral part of the main boiler circulation. The downcomer tubes between the lower drum and the water wall header are located outside the boiler.

The gases, after leaving the last pass of the boiler, pass through a sectional plate type air heater made up of abrasive resistant plates which contains 3600 sq. ft. of heating surface. This air heater supplies 500 degrees F. air to the pulverizer to dry the coal. The outside of the air heater and the air return boxes are insulated with 3 in. of slag wool.

The extended surface type economizer is designed for complete counter current flow and contains 6700 sq. ft. of heating surface. The casing consists of a series of cast iron flanged plates with insulation.

The hoppers under the economizer and under the third bank of tubes in the boiler are equipped with motor driven rotary air locks to connect to the fines return system.

The dust system consists of a primary collector made up of a multiplicity of tubes which separate the fly ash from the main gas stream and then passing the concentrated ash and gas through a secondary collector from which the fine ash is removed through a motor driven rotary air lock. A motor driven blower carries all of the fine ash delivered through these rotary air locks to the lower part of the combustion chamber, where any fuel in this fine ash will be consumed.

The induced draft fan of the multi-blade type is driven by a high pressure steam turbine through a reducing gear unit. The regulation of the secondary air for combustion is by speed control of the turbine driving the induced draft fan. The secondary air enters ports in the rear of the side walls and passes through side walls to the front wall, where it enters the combustion chamber through ports. All flues and air ducts are made of abrasive resisting steel plates and are insulated with 3 in. of slag wool with a ½ in. hard finish. The induced draft fan discharges the exhaust gases into a steel stack 8 ft. diameter by 90 ft. high. The stack is lined with 2½ in. of gunite.

The twenty soot blowers used in the installation are all designed to operate with high pressure steam. Six soot blowers are located on each side of the boiler and four on each side of the economizer.

The ash hopper under the combustion chamber is the full cross section of the combustion chamber and is 9 ft. 6 in. in depth. This hopper is designed with channels and ash removal is by high velocity water jets. A 6 in. centrifugal type ash pump lifts the ash and water from the sump and through a 6 in. ash transport line to the storage tank. This storage tank is of the dewatering

FIGURE 4 *(top)*—Diagram showing high pressure steam piping system.

FIGURE 5 *(middle)*—Diagram of 160 lb. steam line system.

FIGURE 6 *(bottom)*—Sketch showing schematic arrangement of continuous blow-down system.

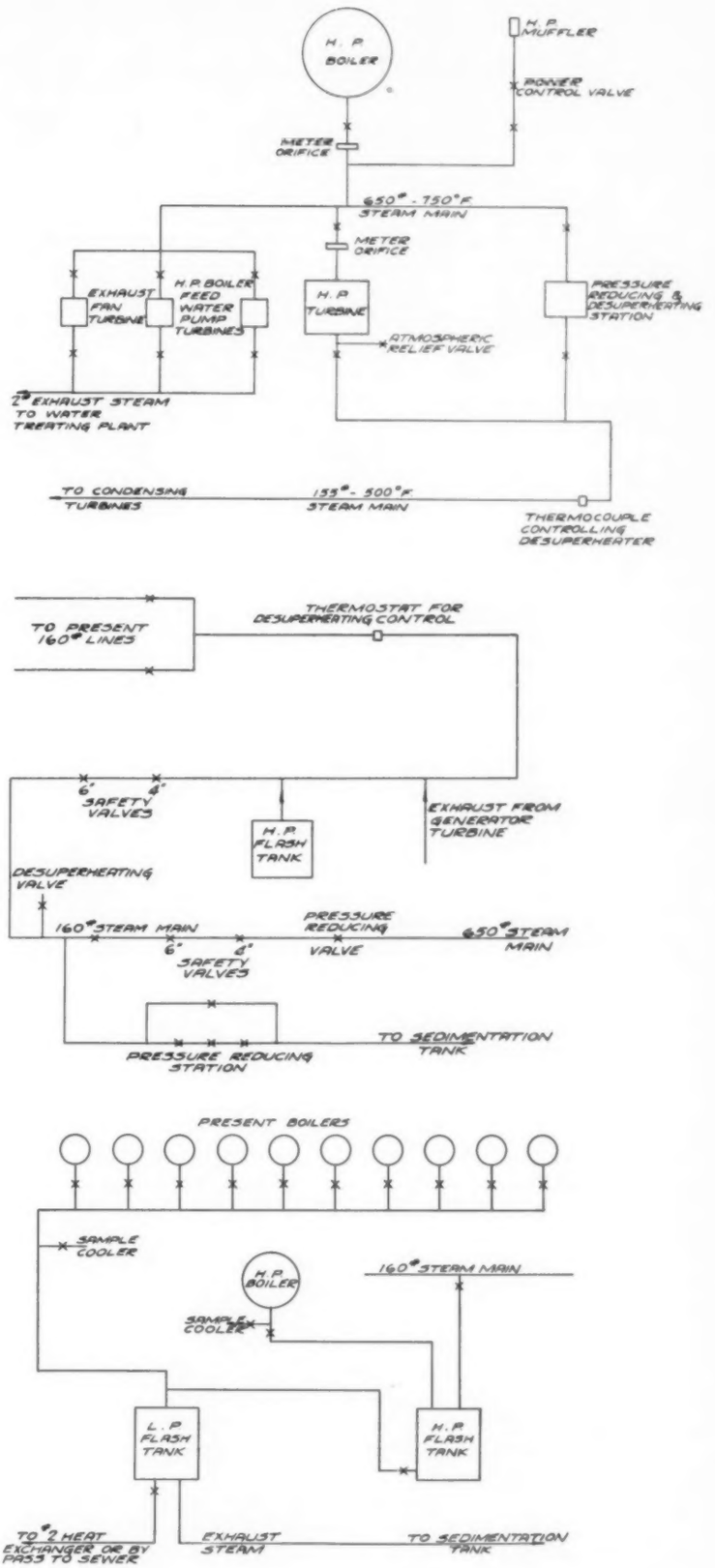
type which leaves the ash commercially dry. Ash is removed from storage tank through discharge opening into car or truck. Water is returned to water supply tank to be used over again.

Coal for operation can be delivered to the plant either by truck or rail when it is used directly or placed in storage yard. The coal is piled in storage yard and taken from storage for use by a diesel powered crawler tractor equipped with bulldozer blade. Coal is handled from the track hopper by an automatic skip hoist to the bunker in the top of power house. This bunker is divided into three compartments. The two outside compartments will hold approximately one carload of bituminous while the center compartment will hold 200 tons of fine anthracite. Chutes with gates under the skip hoist hopper are arranged so that coal can be put in either one of the bin compartments. Chutes from the main coal bunkers carry the coal to the two automatic scales where the weight is automatically recorded. Chutes from the scale hoppers carry the coal to two table type feeders with adjustable shears to vary the feed of the coal to the pulverizer.

The pulverizer is of the conical ball mill type driven by a 350 hp. induction motor. The pulverizer speed is 19.45 rpm. The anthracite fines not larger than $\frac{3}{32}$ in. in diameter are pulverized in the ball mill to a fineness of not less than 85 per cent through 200 mesh. The capacity of the mill is 22,000 lb. per hr. The preheated air enters the mill at one end and picks up the pulverized coal. This mixture of coal and air leaves the mill through a spiral flow classifier where all oversize particles are returned to the mill. The fine coal is carried to the exhauster and then blown through the distributor which divides the fuel-air mixture to the five burners which are located in the flat arch at the top of the front wall. The burners are of the separating type which reduces the amount of primary air that enters the furnace with the fuel. Part of the primary air and the fuel enter the furnace vertically through the horizontal arch and the remainder of the primary air passes out the top of the burner and enters the furnace through vent nozzles located in the lower part of the front wall. The path of the flame is toward the bottom of the furnace in a sweeping curve turning upward toward the first bank of boiler tubes.

The fuel firing system includes an output control damper located at the exhauster inlet together with automatic safety dampers which isolate the mill in case of failure of the power supply. Automatic feed and level controllers regulate the coal feeder in accordance with the demand of the mill.

The feed water, which consists of 100 per cent make up both for the old and new plant, is given a primary and secondary treatment. The primary treating plant



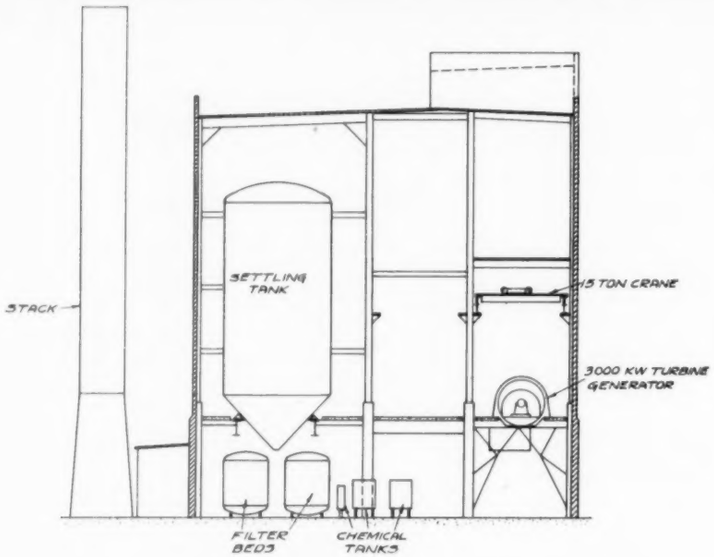


FIGURE 7—Sectional view showing water treating system and turbine.

is the existing cold lime soda intermittent process which has been enlarged by adding an additional settling tank and filter to give longer reaction time. The feedwater is then pumped to the secondary treating plant located in the new power house.

The secondary feedwater treating plant is a continuous hot lime soda system. This system includes a sedimentation tank with a capacity of 320,000 lb. of water per hr. The tank is equipped with an atomizing steam jet deaerating type heater with a compartment for storing deaerated water. It also has compartments for storing desuperheater water, wash water for filters and wash water returns. Four pressure filters are included in this system. The filter beds consist of 18 in. of graded magnetite and 30 in. of graded anthracite. The equipment will include lime and soda tanks, sulphite tank, sulphate tank and phosphate tank with pumps and automatic proportioning mechanism.

Two 3 in. five stage feed water pumps are installed to handle feed water to the high pressure boiler. Each pump has sufficient capacity to supply the boiler. Each pump is direct connected to a high pressure steam turbine.

The feed water to the old boilers is supplied by the existing feed water pumps. Two pound pressure exhaust steam from the auxiliaries of both new and old plants is used to heat feed water. In addition a pressure reducing valve is connected to the 150 lb. steam main to supply make-up steam when auxiliaries do not furnish all demanded by the system. This reducing valve has a capacity of 30,000 lb. per hr., which will take care of full demand.

The high pressure piping for feed water is designed for 825 lb. per sq. in. pressure and 220 degrees F., while steam piping is designed for maximum operating condition of 685 lb. per sq. in. pressure and a total temperature of 750 degrees F. Welded connections are used wherever possible and where flanges are used they are forged or rolled steel with faces made small tongue and groove. The steam main is equipped with a power control valve in addition to the safety valves on the boiler to reduce the closing time to a minimum. This valve is set to relieve at a slightly lower pressure than the safety valves and is electrically closed when pressure becomes normal. This valve outlet is equipped with a muffler.

The high pressure steam main is equipped with a pressure reducing and desuperheating station to reduce high pressure steam to 150 lb. per sq. in. pressure and 500 degrees F. total temperature. This pressure reducing and desuperheating station is of sufficient size to take the total output of the boiler. Ordinarily it will only be used to take the difference between full boiler capacity and steam going to the high pressure turbine. This will vary with the high pressure turbine load. It is desirable to operate the high pressure boiler as near rating as possible. The water used to desuperheat is condensate taken from the vent condenser and given secondary deaeration and stored in a compartment in the sedimentation tank. Duplicate motor driven pumps deliver this condensate to the desuperheater. A temperature control thermocouple placed in the 150 lb. steam main beyond the entrance of the exhaust steam from the high pressure turbine permits the desuperheater to control the temperature of this steam which will exceed 500 degrees F. when the turbine is operating under a partial load.

The continuous blow-down system will handle the blow-down from the high pressure boiler and from the ten low pressure boilers. The high pressure blow-down is flashed into a high pressure tank which is vented into the 150 lb. system. This tank is connected in series with a low pressure flash tank which is vented into the 2 lb. exhaust system. The blow-down from the low pressure boilers is connected to this flash tank. The water from this low pressure flash tank is cooled in the heat exchanger and discharged into the sewer. This system will handle 15,000 lb. per hr. from the high pressure boiler and 10,000 lb. per hr. from low pressure boilers. Sample cooling coils are provided for cooling samples from the boilers and water treating system.

The turbine is of the impulse, horizontal shaft, multistage type. The casings and diaphragms are split at the horizontal center line so that it is possible to remove parts with a minimum of disturbance. The rotor consists of a forged steel shaft with forged steel bucket wheels shrunk on and keyed to the shaft. The shaft is carried on two main bearings and has a solid half coupling which is part of the shaft forging. The valve gear is of the sectionalized non-throttling type consisting of multiple poppet valves lifted in sequence by cams on cam shaft. The constant speed governor is of the centrifugal type driven at a reduced speed through a worm and gear from the turbine shaft. The turbine is also equipped with an emergency governor entirely separate from the main operating governor. This governor is to prevent overspeeding of the turbine and is set to shut down the turbine at 10 per cent overspeed.

The lubricating system consists of a main oil pump and an auxiliary oil pump with twin oil cooler. The main oil pump is of the gear type driven from the turbine shaft through a worm and gear. The auxiliary oil pump is of the centrifugal type driven by a turbine.

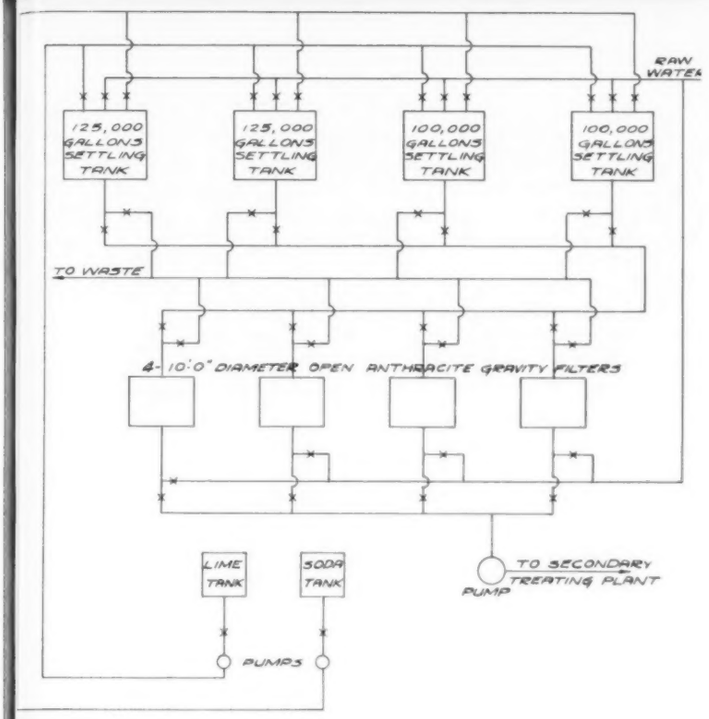
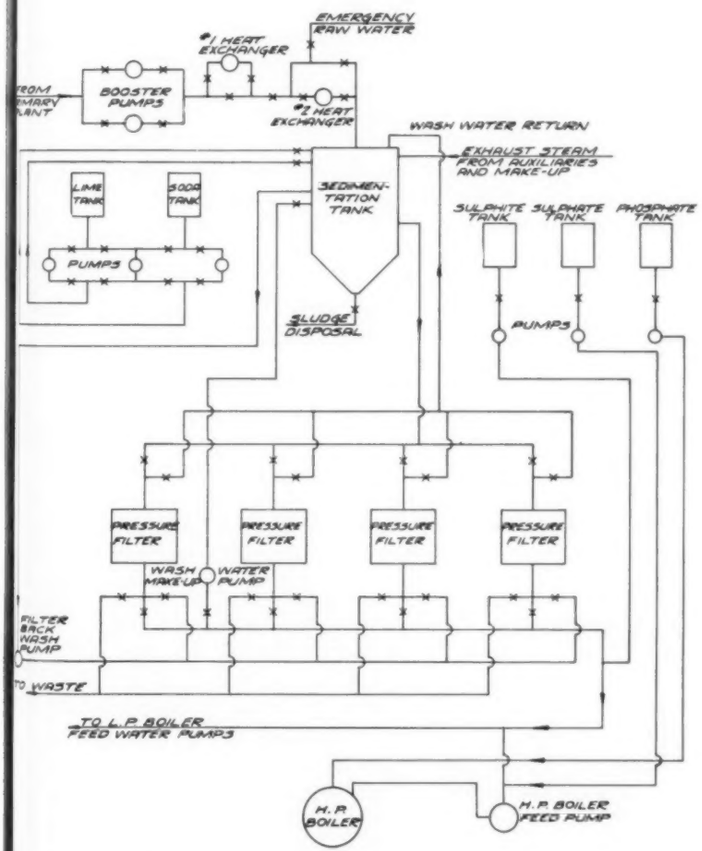


FIGURE 8—Flow diagram of primary water treating plant.

FIGURE 9—Flow diagram of secondary water treating plant.



The auxiliary oil pump is automatically controlled by a regulator which starts the pump when oil pressure falls below a predetermined pressure.

The high pressure turbine will operate at 3600 rpm. and is coupled to reducing gear connected to an alternating current generator to operate at 750 rpm. The turbine will require 33.1 lb. of steam per kw. hr. when operating at full load and 80 per cent power factor with steam at 650 lb. gauge and 750 degrees F. total temperature. The exhaust steam will be 155 lb. gauge and 492 degrees F. total temperature.

The reducing gear is made up of a cast casing split on the horizontal center line. The gears are of the helical type balanced for axial thrust. The pinion and shaft are a solid steel forging while the gear is made of forged steel shrunk on a cast iron hub. The lubrication of the gears is accomplished by a series of special nozzles which spray the oil in thin sheets directly on the gear.

The generator is of the revolving field, self ventilating, totally enclosed type operating at 750 rpm. The rating is 3000 kw., 80 per cent power factor, 3750 kva., 3 phase, 25 cycle, 2400 volts. The generator will be excited by the existing exciters. The field is of the salient pole construction. The shaft and spider is a solid steel forging with laminated pole pieces securely keyed on. The stator frame is constructed to insure strength and rigidity and is completely enclosed with covers at each end to provide channels for ventilating air. The surface type air cooler is of sufficient capacity to cool the generator ventilating air with cooling water at 90 degrees F.

DISCUSSION

PRESENTED BY

L. F. COFFIN, *Superintendent*, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland.

H. C. SIEBERT, *Combustion Engineer*, Bethlehem Steel Company, Bethlehem, Pennsylvania.

N. C. BYE, *Chief Engineer*, Henry Disston and Sons, Inc., Philadelphia, Pennsylvania.

R. L. ASHLEY, *Assistant Director*, Intersystem Power Utilization Bureau, Consolidated Gas, Electric Light and Power Company, Baltimore, Maryland.

L. V. BLACK, *Electrical Superintendent*, Bethlehem Steel Company, Bethlehem, Pennsylvania.

F. C. SCHOEN, *Assistant Master Mechanic*, Midvale Company, Nicetown, Philadelphia, Pennsylvania.

G. J. WALZ, *Assistant Electrical Superintendent*, Bethlehem Steel Company, Steelton, Pennsylvania.

F. O. SCHNURE, *Electrical Superintendent*, Bethlehem Steel Company, Sparrows Point, Maryland.

S. T. POWELL, *Consulting Chemical Engineer*, Baltimore, Maryland.

L. J. GOULD, *Assistant Chief Engineer of Construction*, Bethlehem Steel Company, Bethlehem, Pennsylvania.

W. P. HALL, *Steam Engineer*, Bethlehem Steel Company, Sparrows Point, Maryland.

A. G. DARLING, Industrial Department, General Electric Company, Schenectady, New York.

L. F. COFFIN: It is always interesting to hear a paper on a new project; especially a new boiler plant—and many of the features of this plant are novel. Is it not an unusual construction, to place the economizer after the air heater? Is there any special material used in the air-heater, in order to stand the increased temperatures on account of it being ahead of the economizer. What is the expected temperature of the flue gases entering the heater? I presume that on account of the unusual character of the fuel being used three walls were refractory air-cooled. Is that correct?

What is the particular advantage of using anthracite in the water filter? Is it on account of the fact that it has particular merit over sand or because it is available at reduced price?

What type of desuperheater is used—in order to desuperheat the 150,000 lb. of steam per hr.?

H. C. SIEBERT: Mr. Coffin asked a question as to the reason for air-cooling of the walls. Mr. Johns spoke of the moisture in the coal. It will not be dried in separately fired dryers, but will enter the pulverizer wet. The moisture will be eliminated sufficiently so that the 500 degree preheated air sweeping through the pulverizer will carry the coal through the ducts and burners without clogging them. The coal at times will have 18 or 20 per cent moisture, and this will prevent furnace flame temperature reaching the point at which brick erosion takes place. In addition, the ash fusion temperature is fairly high, probably above 2300 degrees F. These two factors will prevent the furnace flame temperature exceeding 2350 degrees F. This with the air cooled side walls will result in temperature of 2100 degrees F. on the hot face of the brickwork. Hence, there is little danger, we believe, of erosion of the furnace surfaces of the brick setting. In fact, our examination of similar plants that have been in operation for four years has shown that no erosion of the hot surfaces has taken place.

Another question Mr. Coffin referred to was why we placed the air preheater next to the boiler and whether special metal was used in the preheater. The reason for this arrangement lies in the fact that high air preheat is required in the pulverizer, 500 degrees F. This will flow through the pulverizer and dry the coal to the point required. The air preheater therefore will demand a gas temperature of about 750 degrees F. As the gas will leave the boiler at this temperature it demands location next to the boiler. The gas and air temperatures are such that it is not likely that condensation of water vapor of the flue gas will take place, hence special material was not considered necessary in the air preheater; it is made of ordinary steel.

N. C. BYE: Nearly every industrial plant now is faced with a somewhat similar proposition and it is relatively new for this type of application. I think there are many questions a lot of us would like to ask, but I don't think it would be quite fair to Mr. Johns to ask all of them. However, I would like to ask what special precautions in pulverizer or burner adjustments have to be taken in the changing from firing with bituminous to anthracite coal? Second, what special provisions had to be made in the mill to pulverize both anthracite and bituminous coal satisfactorily?

There is also a question in regard to the air cooled walls. Where is the air which is passed through the air cooled walls drawn from, and how is it controlled? I would also like to know if I understood correctly that the make-up water is 100 per cent, as it seems rather high.

The governing of the topping turbine in this type of installation can be done in many different ways, depending on the results desired. I would like to know how this turbine is to be governed and what factors determine the manner in which it is to be done.

R. L. ASHLEY: I have appreciated very much this opportunity to hear something of the developments in the power production trends for the steel mills. You know we are interested in Baltimore in coordinating our power supply with that of the Sparrows Point plant in order to get the best over-all results, so we are naturally interested in any developments in power generation in steel mills.

There have been so many questions asked that I hesitate to add any more, but I would like to know what determined the choice of temperature and pressure for the topping turbines in this particular instance.

L. V. BLACK: Is all the steam that goes through the topping turbine delivered to the plant system, or does it go to the lower pressure turbines?

F. C. SCHOEN: I would like to know something about the percentage of returns from the air cleaners, and what effect it will have on smoke reduction.

Also, why is the phosphate added directly into the boiler, and will addition at this point have any particular effect on the steam piping?

G. J. WALZ: I am like most steel mill men who have purely electrical maintenance and operating responsibilities. Whenever the steam generating plant is mentioned, there seldom occurs to me an appreciation of all of the blessings, which normally flow to us from our boiler plant, whenever it is running well, but rather do I think of the electrical delays, which are caused by low steam, and the large part, which the proportionately heavy steam cost plays, in the total cost of generating electricity.

There is one thing, however, which is most amazing to me, and that is a mental comparison between this up-to-the-minute 1940 boiler plant, which has been so interestingly and ably described, and the sadly primitive first power plant with which I ever came in contact, back in 1896. The progress and improvements which have been made in the art of generating steam are really remarkable; fully, I would say, equal to those which have been achieved by the builders of turbines, generators and transformers, etc., in their respective products.

F. O. SCHNURE: In view of the fact that the utility in our territory is installing a topping turbine at 1250 lb., I would like to inquire what factors in the study influenced the selection of pressure at 650 lb. Also, why was the capacity of the turbine not chosen more nearly the capacity of the boiler? I appreciate the fact that there may be times when the electric load is light and the auxiliary steam load in the plant high, and that may be the reason. A station such as this represents a fairly high cost per kw. installed, which would be lowered by

increasing the capacity, all of which depends on whether it is required.

It is very evident that Lebanon is operating under a handicap due to condenser water and it would seem that central station service would be able to give them rather close competition.

No doubt all of this has been carefully considered by the Lebanon engineers; nevertheless in these days of specialization, at times the question arises whether the steel manufacturer should make steel and power, or just steel.

S. T. POWELL: It was my privilege and pleasure to have worked on this project. I think it is a graphic illustration of the trends of the times in the development of the high-pressure boiler plants in the industry. Possibly the problem in the steel industry and in the utilities is somewhat different. However, we all know the public utilities have gone to rather high pressures, and more recently to topping turbines. I think that industry has taken a leaf from the book and gone to the topping turbines because of the economy to be effected.

This plant presented some rather unusual conditions —the principal one was the shortage of water at this location. There were three types of plants we might have used and consideration was given to each possible type. As Mr. Johns stated, there was a water treating plant that had been in service for many years and which had given satisfactory service for the low-pressure boilers, but the quality of the water was not satisfactory enough for use of the high make-up plant which was to be 650 lb. pressure.

We considered, therefore, two other types of plants. I think this will answer one of the questions asked, as to why we use phosphate internally in the boiler. We could have used a zeolite softener using as the water supply the effluent from the present system and could have produced a satisfactory water. Such treatment would have required reduction of the alkalinity by means of sulphuric acid. We didn't think this was a good practice in this particular mill, although we have used acid at other plants.

There was another objection to the use of zeolite, and that was the shortage of water. Where a zeolite softening system is used, a large amount of water must be wasted. In this plant it would have meant a gross waste of some 40,000 gallons of water a day, and it was apparent the company could not stand the wastage of that much water.

A hot process softener could have been selected. This treatment was selected because of the economy to be effected, and it made possible the use of water from the primary softener. Such treatment had two distinct advantages. First, the system combined the heater and the softener in one unit, and in addition to this it also provided a possibility, at a little later date, of converting the hot process softener into the hot phosphate softener. In such a system the phosphate is used for improving the quality of water over that which is obtainable from straight hot chemical softener.

However, we have eliminated the phosphate type of treatment for the present time and the phosphate will simply be used as a secondary treatment in the boiler itself. Where phosphates are used externally to the boiler, there are apt to be deposits—so, phosphate solution will be added directly to the boiler drum.

I would like to say that it is planned to add the phosphate solution beyond the point where the steam is washed. This explanation will answer the question raised by a previous speaker as to why phosphates were added in the boiler and what would be the effects on the steam quality. As the phosphate is added in the drum proper, deposits will lay down in the drum as a soft material, which can be readily washed from the boiler.

It is our belief that this boiler can be left on the line for three or even six months and when it becomes necessary to wash it, this can be done by using soft brushes and flushing with water. There are a number of installations of this kind, and they all have operated without any trouble. At one plant where we have operated a similar system, we have cleaned tubes out at the rate of one in five minutes, so it is apparent that is no problem to keep the tubes free from scale or adherent sludge.

L. J. GOULD: About the selection of the equipment, one of the reasons for the pressure selection is, I believe, that once you go beyond 700 you jump the code size, and the expense is increased, so the choice is to stay there or go as far as the utility people did in Baltimore—but half-way figures are no good at all.

Another thing that was brought to my mind about the size of the turbine unit, by discussion recently on another plant, is that when you use a topping turbine and consider a base load station, as we hope to consider this one, you must also be able to make use of all of the steam that passes through the topping unit, so in this case it is not an addition in steam capacity for 3000 kw. but even without the by-pass it is close to 6000, and with the by-pass it is over that.

So the problem arose in selecting the particular turbine that will work continuously enough to pay for the investment, not only by itself, but with other turbines in which the exhaust will be used. In this case capacities of the topping unit up to 6000 were checked and the 3000 was decided on.

W. P. HALL: I was interested in the question about alkalinity in the boilers, and also on the kwh. water rate, which showed 33 lb. on high pressure and 20 lb. on low pressure. These seem to be high water rates.

S. T. POWELL: In further explanation of the need for sulphuric acid treatment prior to the application of the water to the zeolite mineral, this is necessary in order to reduce the alkalinity to a point where the zeolite softening material will not be detrimentally affected by the high alkalinity in the chemically treated water which is present when the water leaves the primary treating system.

A. G. DARLING: Another way of expressing the effectiveness of a non-condensing turbine is to invert its steam rate into kwh. per 1000 lb. of steam. For instance, Mr. Johns showed in Table 1 a steam rate of 33 lb. per kwh. for the 3000 kw. high-pressure unit, and 20 lb. per kwh. for the low-pressure units. If expressed in the inverse ratio, the output of the 3000 kw. unit would be 30 kwh. per 1000 lb. and of the low-pressure unit it would be 50 kwh. per 1000 lb. Since the steam from the high-pressure boiler makes kwh. in both high and low pressure turbine units, the plant output is 80 kwh. per 1000 lb. or an increase of 30 kwh. per 1000 lb. over the low pressure condensing plant.

There has been some discussion regarding the advantages of using superposed turbines. I am reminded of that interesting paper with which you are all probably familiar, "Fourth Steam Station Cost Survey" by A. E. Knowlton. Those who haven't seen it would profit from it very materially. The data given therein is a compliment to the superposed machine, it seems to me. Mr. Knowlton concludes that the turbine superposed on an existing low-pressure plant shows no better economies than the new condensing plant operating at the same overall steam conditions. If the two plant economies are equal, it would be better than most of us would expect because it is not usual to find an existing low-pressure condensing plant with economies equal to the low-pressure part of a new, high-pressure condensing turbine. So, if in his survey he has found that the superposed turbine is as good as the full condensing plant, it is a sincere compliment to the superposed turbine.

Some of the other discussion has run along fhe line of advantages or disadvantages of adding high-pressure versus continuing the old pressures. The combination of low-pressure plant with superposed unit will consume something like a pound of coal per kwh. I think you will find that the low-pressure straight condensing plant consumes a pound to a pound and a half of coal per kwh. So there is considerable to be gained in adding a high-pressure turbine to a low-pressure plant as compared with the extension of the old low-pressure plant.

We will all be very much interested to know how Mr. Johns is going to govern his turbine. At Weirton the high-pressure non-condensing unit is governed, I believe, now, for practically constant steam output to meet conditions when heavy drafts of steam are made for mechanical uses. Initially, they allowed the low-pressure frequency-governed machines to determine the output of the high-pressure machine. Later, I believe, they found the high-pressure installation was so economical that it paid to keep its output at a constant level and let the low-pressure boilers take the excess demands of steam because the variable uses of the steam were at the lower pressure. The load factor of this turbine has been high. It is better than 100 per cent if the possible output is expressed in terms of the eight-tenths power factor rating of the generator.

H. U. JOHNS: In answer to Mr. Coffin's questions, the more usual position of air heater and economizer is reversed due to the fact that we desire 500 degrees F. air in order to dry coal in the pulverizer. Mayari "R" steel plates are used in the air heater in order to resist corrosion and abrasion. Heat resisting metal is not necessary, as the temperature of gas leaving the boiler is 750 degrees F. Three walls of the furnace are air-cooled because this type of wall works hotter than water-cooled walls, which is desirable for ignition when using coal of low volatile content. Anthracite coal is used in the water filters because of the low silica content. The desuperheater is of the jet type.

Answering Mr. Bye, the equipment as installed will pulverize and burn either anthracite or bituminous coal without change. No special provisions are made in the mill in order to effect this. However, when pulverizing bituminous coal alone some cold air is admitted into pulverizer along with hot air.

Secondary air which passes through air-cooled walls is taken from boiler house and enters air-cooled side walls at the rear end and passes horizontally through side walls to front wall, where it enters the combustion chamber through ports. Each air passage is equipped with a damper at the inlet end which is set manually to give equal flow in each passage. The amount of air used is regulated by the automatic control of speed of induced draft fan. One hundred per cent of the feed water is make-up, no returns being used.

The new boiler will supply about half of plant steam requirements. Over 90 per cent of total steam is used for power generation. New turbine will be operated at full load practically all of the time. Balance of high pressure steam will pass through pressure reducing valve and desuperheating station into low pressure steam lines to condensing turbines. The low pressure boilers will take the balance of the loads.

I believe Mr. Ashley's question has been answered by Mr. Gould's remarks, as has Mr. Schnure's question. Answering Mr. Black, all of the exhaust steam from the topping turbine goes into the 150 lb. system of which over 90 per cent is used for power generation in condensing turbines.

In answer to Mr. Schoen, the dust collector will remove a large part of the fines from waste gases. The remainder of his question has been answered by Mr. Powell. Mr. Hall's comment has been answered in Mr. Darling's remarks.

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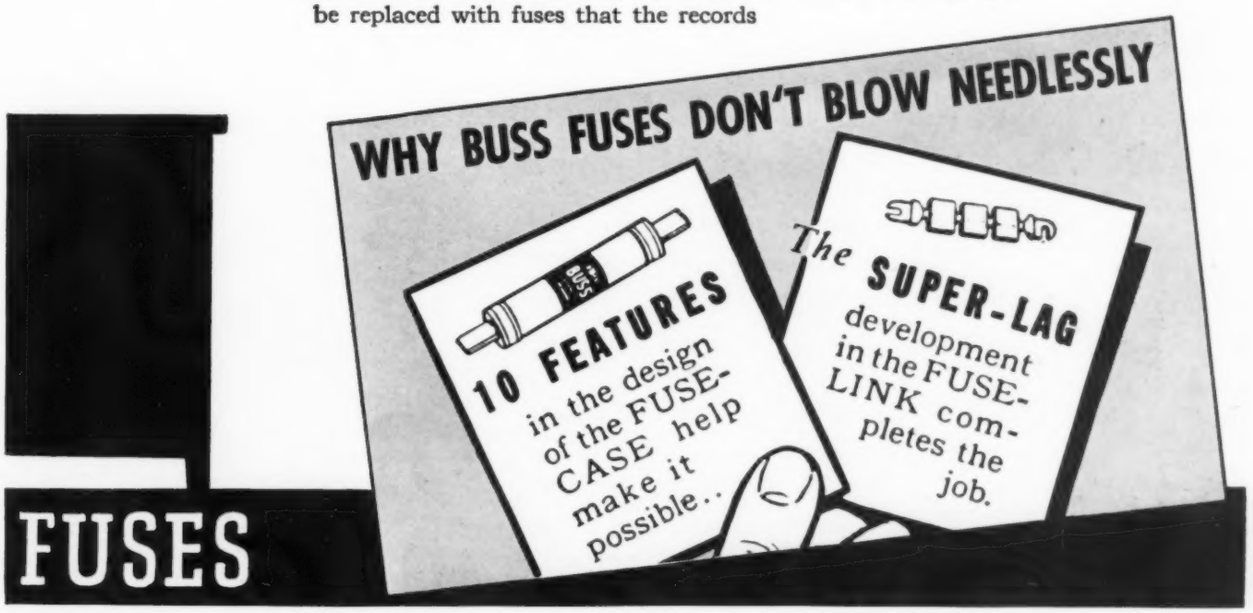
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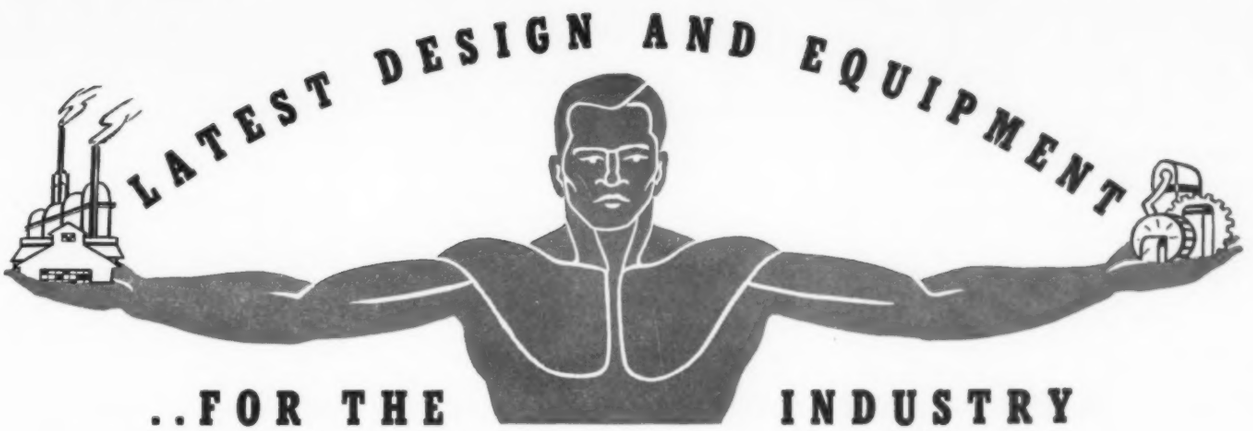


BETHLEHEM STEEL COMPANY ANNOUNCES $18,000,000 STEEL PLANT EXPANSION

▲ Bethlehem Steel Company has announced an expansion program involving a total cost of approximately $18,000,000, which will add nearly 850,000 tons of steel ingots, 800,000 tons of coke and 700,000 tons of pig iron to its present annual production capacities.

The program includes installation of six additional open hearth furnaces, two batteries of coke ovens with additions to one of the existing by-product plants, erection of two new blast furnaces and the rebuilding and enlarging of two electric steel furnaces with annual capacity of 120,000 tons. Other facilities will also be installed, all of which were authorized earlier.

Expansion will be carried out at the Bethlehem, Lackawanna, Maryland, and Steelton plants. The new program will be completed within a year with some facilities available in six months. Including the newly authorized expenditures, the total cost of all facilities constructed or authorized by Bethlehem in 1940 will exceed $50,000,000. In addition other facilities costing over $50,000,000 are being constructed at various plants and shipyards of Bethlehem Steel Company, and will be paid for and owned by the government.

According to the latest published figures of the American Iron and Steel Institute the capacities for Bethlehem Steel Company are: coke—7,093,000 net tons; pig iron and ferro-alloys—7,379,000 net tons; and steel ingots and steel for casting—11,468,000 net tons.

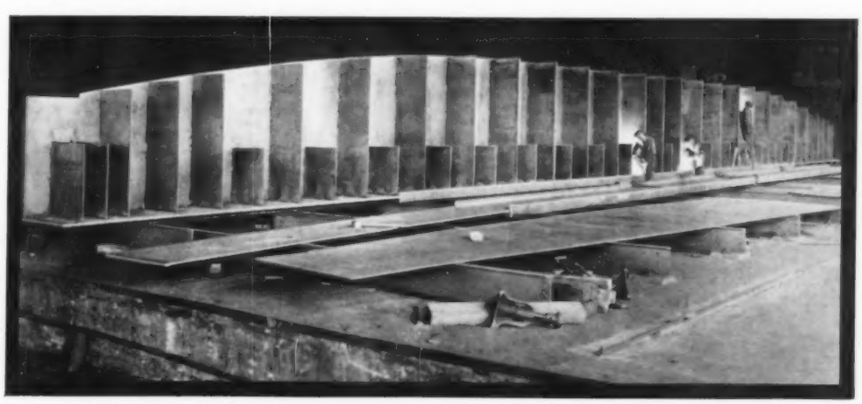
FABRICATES LARGEST WELDED CRANE GIRDER

▲ A giant all-welded girder for a Cleveland overhead traveling crane has been constructed by the Cleveland Crane and Engineering Company. This is the world's largest all-welded crane girder.

Plates ranging in thickness from 7/16 in. to 1¼ in. are being welded into position. This girder when completed will weigh 45 tons, have a span of 105 ft. and be over 8 ft. high at the middle. The girder will be stronger and more rigid for its weight than possible by any other method of construction.

The reinforcing diaphragms are welded not only to the web plates, but also to the top plate, an advantage exclusive with the welded construction. The diaphragms are spaced so close that they alone will support the trolley rails without depending on the top plate, thus eliminating possibility of plate cracking.

This all-welded crane girder, the world's largest, was fabricated by the Cleveland Crane and Engineering Company



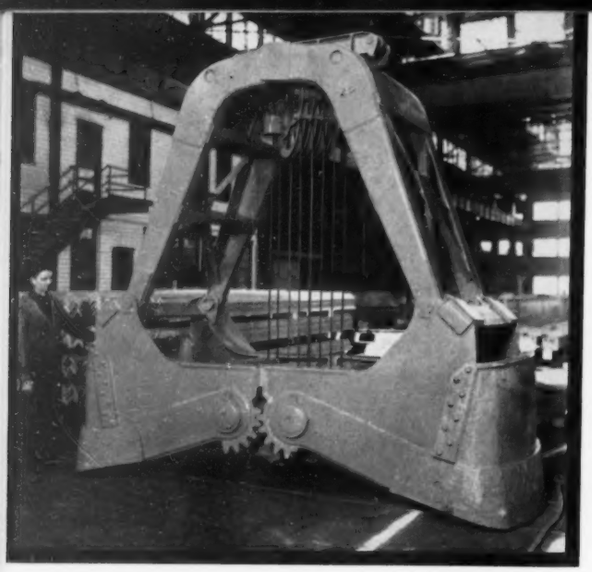
REPUBLIC ANNOUNCES MORE ARC FURNACES

▲ Republic Steel Corporation plans to build two more 50-ton electric furnaces at the Canton, Ohio, Works. These, in addition to those announced in the August and October, 1940, issues of the IRON AND STEEL ENGINEER, bring Republic's electric furnace equipment at the Canton Works to six of 50-ton capacity, three of 25-ton capacity, three of 15-ton capacity, and two of 6-ton capacity.

A. M. BYERS COMPANY TO PRODUCE ALLOY STEELS

▲ A. M. Byers Company announced that it would enlarge its activities to include the production of a broad line of alloy steels, including stainless. Production will begin within four to six months. An addition will be built to the company's Ambridge, Pennsylvania, plant and will be used as a melt shop for new electric furnace equipment that is to be installed. Other basic production equipment for heating and rolling alloys already is in existence within the plant.

Initial products will be billets and bars for alloy steel fabricators. Pro-



Clamshell buckets continue to get bigger and better. This welded all-alloy steel "four rope" slag handling bucket, installed recently in the open hearth department of a district steel plant, was made by the Blaw-Knox Company. The bucket weighs 17,000 lb., has two closing and two holding lines, and uses 10 parts reeving. It can load a car in 16 grabs.

duction of alloy steels, for which there has been a constantly growing market, will not conflict with the wrought iron production.

GEAR STEEL STOCKED FOR QUICK SHIPMENT

▲ Users of S.A.E. 4640 steel will be interested to know that this gear steel is now carried in stock for immediate shipment by Joseph T. Ryerson and Son, Inc. Stocks include hot rolled annealed rounds, in sizes from 1 in. to 5 in.

Because of its high fatigue resistance, toughness, and ability to attain a high degree of hardness with minimum of distortion in heat treatment, S.A.E. 4640 is one of the best gear steels of the medium carbon grades. It will develop high hardness and tensile strength with a relatively mild quench. This mild quenching operation, together with the stability and balance of the alloy itself, tends to produce less distortion in the finished part than when other steels of the same general type are used. It also shows higher impact resistance at high hardness than other .40 carbon alloy steels in the same or slightly lower price range.

The machineability of both annealed and heat treated S.A.E. 4640 is superior to other steels of this type. It can be satisfactorily machine-finished at 400 Brinell. Nickel molybdenum steels of this type in the hardened condition will resist cracking under severe surface grinding better than many other alloy steels at equal hardnesses.

In addition to gear use, S.A.E. 4640 is recommended for arbors, racks, worms, boring bars, spindles, clutches, piston rods, bolts, studs, ratchets, pins, and other applications where resistance to shock and great toughness are necessary at relatively high hardnesses.

MILL REHABILITATION TO INCREASE CAPACITY

▲ Youngstown Sheet and Tube Company has awarded a contract for reconstructing the billet mill at the Campbell, Ohio, Works to the Morgan Construction Company, the firm which built the original mill. The light stands will be removed and replaced with heavier equipment and the mill will be able to produce around 200,000 tons greater tonnage a year. The rebuilt mill will be able to take larger sections from the blooming mill.

EXPERIMENTAL WORK ON NEW KRAUSE COLD MILL

▲ Experimental work is progressing on the cold reduction of ferrous and non-ferrous metals into thin gauge strip under a newly patented process developed by F. R. Krause of the Lewis Foundry and Machine Division of Blaw-Knox Company. The process (described in detail in the August, 1938, issue of IRON AND STEEL ENGINEER) is intended principally for the cold reduction of all kinds of metals to sheet or strip form. It can be used by jobbing shops and fabricators.

Tests are being run on non-ferrous metals, including zinc, copper, brass and aluminum, as well as carbon and alloy steels, including stainless. The unit is of reciprocating type in which the housing on the smaller machines or the work piece and cross head on the larger machines are moved back and forth by means of a crank drive. The work piece is fed into the machine in small increments per crank cycle. As it advances, the work piece comes into contact with the rolls, which reduce it to a wedge shape and eventually extend it into a parallel section of the finished gauge of the material rolled. The length of this parallel section or flat reduced strip depends on the feed of the original or entering section of the blank and the capacity of the mill for which it is designed.

New demountable steel compartment for industrial truck batteries developed by Edison Storage Battery Division of Thomas A. Edison, Incorporated. This compartment permits quick exchange of entire unit, including battery, and provides secure attachment to truck. The use of demountable compartments is growing due to increased number of industrial trucks operating 16 to 24 hours a day.

The rolls in this mill are 3 to 4 in. in diameter. They are backed up over the length of their body by cam plates fixed into the mill housing. These plates serve the function of the back-up rolls used in 4-high mills. The rolls move back and forth on these cam plates as the machine is moved back and forth by the crank drive. The rolls are mounted in the housing on a patented floating principle which leaves them free to accommodate themselves to the rolling motion imparted to them by the cam plates on the one hand and the blank on the other hand as it elongates under the rolling pressure.

The process permits rolling of light gauges from relatively heavy stock in a single pass through the mill without the necessity of annealing. Power requirement for the operation of the mill is relatively small. The lighter the gauge rolled, the less power required for a given length of strip per minute. Gauge and cambers are controlled by the mill operator. In operation the unit requires no highly skilled operators and its design is such that a crew of two or three men could operate a line of several machines. Principal application will be for tin plate and fabricators requiring cold-rolled material who can find it economical to produce their own either from sheet bars, plates, or hot-rolled strip in coils. The machine is simple in construction and ease of operation.

ARMCO PROGRESSES WITH BROAD MODERNIZATION

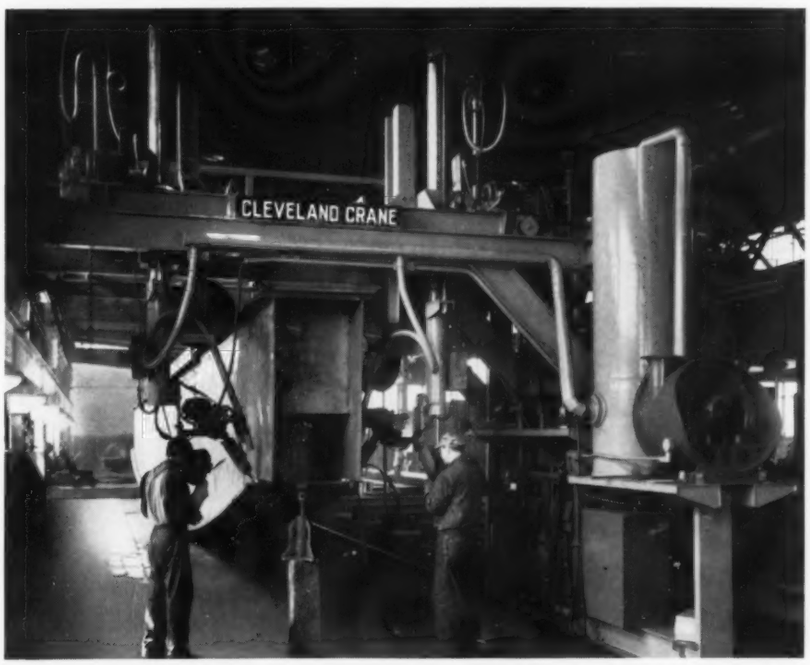
▲ American Rolling Mill Company's No. 2 blast furnace at Hamilton, Ohio, returned to production recently after being out of operation since August 15. During this period the furnace was completely remodeled and its size doubled from 350 tons daily production to 700 tons, at an estimated cost of about $500,000.

Numerous other improvements are also being made at the Armco plant in Hamilton. Most important are the construction of 25 by-product coke ovens, the installation of a turbo blower which will speed pig iron production, and the enlargement of the ore yard. The total cost of these improvements is estimated at $1,500,000.

At Ashland, Kentucky, American Rolling Mill Company announced that the jobbing mill will be modernized and re-built at an estimated cost of $1,000,000. Modernization of the Ashland jobbing mill will make it possible to roll sheets of wider widths and better quality. At the same time it will give this plant a greater diversification of products by permitting it to compete for orders it cannot now make because of width limitations.

The new jobbing mill will have rolls 68 in. wide, producing sheets up to 63 in. wide. It will consist of six stands of rolls; two stands of three-high and four stands of four-high. United Engineering and Foundry Company has been awarded the contract for furnishing the new rolling units. Because of the present large volume of orders on the books, construction work will not begin until late next spring, at a time when it can be pushed through with the least amount of interference with production.

The Ashland mill was the first continuous sheet rolling mill ever built. It began operations experimentally late in 1923, and got into production in 1924. So successful was this revolutionary rolling process that today all the major steel companies in this country and two in foreign countries are licensed to use it.



120-FOOT BEADS WELDED AUTOMATICALLY

To assure all-welded girders having the greatest strength and rigidity, it is important that the long longitudinal welds be placed at a definite rate of speed and be continuous from end to end.

For this work an automatic welding gantry was especially designed and built by Cleveland Crane. As the gantry travels the length of the girder, the welding rod is fed precisely and automatically to both sides. The rod used is especially made for the purpose, having characteristics which are essentially the same as the parent metal.

Equipment like this is one of the reasons why girders for Cleveland all-welded Cranes are stronger and more rigid for their weight than obtainable with any other method of construction.

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES
ALL-WELDED OVERHEAD TRAVELING CRANES
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

NEW FREQUENCY METER INDICATES VIBRATIONS

▲ A new vibration frequency meter, weighing only 8 oz., and designed to aid the engineer in ferreting out the causes and cures of troublesome machine vibrations, is announced by the Westinghouse Electric and Manufacturing Company. The new instrument is no larger than an engineer's slide rule, but it can indicate what frequencies between 500 and 20,000 cycles per min. are present in a vibrating body.

This compact device is built around the principle of the vibrating-reed, and consists of a thin spring steel vibrator clamped at one end between a set of steel rollers. A knurled knob connected to the rollers permits their rotation, and moves the steel reed in or out, changing its frequency of vibration. A sliding pointer on the back end of the steel reed indicates the vibrating frequency which is read off the calibrated scale on the frame of the instrument.

To use the meter, its head is held

against the vibrating body and the adjusting knob rotated until the vibrator reed moves to and fro at maximum amplitude. If more than one vibrating frequency exists, there will be a point of maximum amplitude for each, and vibrations in differing planes may be detected by changing the axis of the meter. The meter is very sensitive. It will indicate a vibration whose double amplitude is .0001 in. or greater. It can measure harmonies of basic vibration frequencies. Although not designed to measure the amount of vibration, it may be used as a rough indicator of its magnitude.

The meter is solidly constructed of high strength steel, and will stand all normal rough treatment without losing its calibration. Because all moving parts are direct connected, *i.e.*, no gears or gearing employed, back-lash is non-existent in the adjusting knob, and the indicating scale.

TIMKEN WILL EXPAND VARIOUS FACILITIES

▲ Timken Roller Bearing Company has announced a three million dollar expansion program, designed to meet defense requirements, which is now under way at the Canton, Gambrinus, Columbus, and Mt. Vernon plants, all located in Ohio. The entire program involves an immediate expenditure of $2,217,400 with projected additional expenditures which will bring the total to the three million dollar mark.

A new 100 ft. x 275 ft. forge shop, a 65 ft. x 300 ft. mould conditioning building, and a 105 ft. x 105 ft. melt shop addition will greatly expand the steel and tube division's manufacturing facilities. At Gambrinus a 10,800 sq. ft. box factory, 32,000 sq. ft. tube storage and 62,000 sq. ft. bearing factory addition are being constructed. At Columbus a 40 ft. x 400 ft. building being erected now will house a hospital, canteen and employment rooms. Four thousand six hundred sq. ft. of floor space are being added to the main building of the Mt. Vernon rock bit factory. A truck loading dock at the Canton bearing plant will add 2000 sq. ft. of space and give the shipping department additional loading outlets.

Included in this program is the new 60 ton electric furnace and auxiliary equipment which was announced in the November, 1940, issue of the IRON AND STEEL ENGINEER.

TUBULAR ELEMENTS FOR IMMERSION HEATERS

▲ Recent developments have now made available a new line of tubular immersion heating units in diameters from 5/16 in. to 1/2 in. inclusive, and in lengths from 12 in. to 8 ft. These tubular elements, developed by Edwin L. Wiegand Co. are used extensively in water, oil, air and molten metal and molten salt heating; are constructed with a helical coil of nickel chromium resistance wire, imbedded in a refractory material, which is encased in a metal tube. Copper, steel and special high temperature alloy sheathing for operating at a maximum temperature of 1200 degrees F. are used, based upon operating conditions of the heating application.

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Results in a better product because it gives a correct indication of furnace atmospheres. Built husky enough to stand the severest steel mill conditions yet sensitive enough to register accurately in increments of .0025 in. water. Employs the famous Hays Slack Leather Diaphragm—self sealing—not damaged under sudden excess pressures. Two draft values, two pressure values, two differential values, or a combination of any two of these three values may be recorded. Or a temperature recorder may be substituted for one of these values. Send for descriptive literature. Write to 955 Eighth Avenue, Michigan City, Indiana.
The HAYS CORPORATION
SINCE 1901
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

REPUBLIC TO INSTALL NEW COLD STRIP MILL

▲ Republic Steel Corporation will increase the cold strip capacity by nearly 50,000 tons annually with the installation of a cold strip mill at the Warren, Ohio, plant. The new mill, which is expected to go into service during the spring of 1941, will replace 2-high mills which have become obsolete.

This major improvement is a tandem three stand, 4-high cold mill with 9½ in. work rolls and 22 in. back-up rolls. It will cold roll strip up to 18 in. in width.

In addition to the finishing mill, the company is also installing a 2-high temper mill and an improved gang slitter. Hot strip for the new mills will be produced at Warren, where hot strip storage capacity is being increased through the construction of a new storage and shipping building 400 ft. long by 160 ft. wide.

PHOTOGRAPH COURTESY THE AMSLER-MORTON COMPANY
Rule of thumb steel making
COSTS TOO MUCH TODAY
DAYS when guesswork could be tolerated in a steel mill belong to the past—guesswork costs too much today. Spoilage—lost time and material—inefficient operation—these things rob a plant of profits.
Good steel men no longer depend on a "guess" to control Combustion Conditions in a furnace, an open hearth or a soaking pit. It spoils steel, wastes fuel—cuts down profits.
Hays Combustion Instruments have set the standard for accuracy, dependability and stamina for 38 years. They are as well known in the steel mills and power plants of the country as a monkey wrench. They can be designed to meet practically any requirement concerning indicating, recording and controlling of combustion conditions. Hays Engineer-representatives are located in all the principal cities to help industry in the solution of its combustion problems. They will be glad to serve you. Write to 955 Eighth Ave., Michigan City, Indiana.
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MICHIGAN CITY, INDIANA, U.S.A.

COVERED ELECTRODES FOR MANUAL WELDING

▲ An addition to the line of "Murex" covered electrodes for manual arc welding has been introduced by the Metal and Thermit Corporation. The new electrode, known as "Murex Alternex" is designed especially for use with transformer type a-c. welding equipment and is said to handle extremely well in all positions, including vertical-down-welding. In the smaller sizes, it may also be used to advantage in welding light gauge steel.

AIR CONDITIONING FOR BLAST FURNACE GAINS

▲ Jones and Laughlin Steel Corporation will install air conditioning equipment capable of removing from seven to forty tons of water per day from the air blown into one of the world's largest blast furnaces, in order to more closely control the quality of the iron produced. This new air conditioning equipment will be installed on the No. 1 blast furnace at the Aliquippa Works. This is the first modern air conditioning unit to be installed in the North for conditioning the air blown into a blast furnace. The equipment will be used to maintain a constant low moisture content in the air blast, eliminating the necessity of trying to out-guess the weather 24 hr. in advance of charging the furnace. Due to the fluctuating moisture content of the atmosphere, operators must constantly change the proportions of raw materials charged into the furnace, which approximate 2000 tons of iron ore, 950 tons of coke, 500 tons of limestone, and 4000 tons of air per day to produce 1000 tons of molten pig iron.

Ordinarily, wide fluctuations in humidity cause irregular blast furnace operation, which results in less iron production. On hot, humid days, more coke must be charged per ton of iron to offset the excess moisture in the air, which is blown into the furnace at the rate of 80,000 cu. ft. per

min. This air carries with it into the furnace seven tons of water per day for every grain of moisture content per cu. ft., which has the effect on extreme days of pouring thirty or forty tons of water into the furnace.

With an air blast of constant humidity, it is possible to control the silicon content and iron temperature within narrow limits which are two major factors having a direct bearing on steel quality. With such iron, the production of steel by both the Bessemer and open hearth processes can be increased. Further advantages are seen in a possible reduction in the amount of coke and limestone necessary to produce a ton of iron and an actual increase in iron production may be expected.

The air conditioning equipment, which will be furnished by the Carrier Corporation and installed by the Dravo Corporation, conditions the air by drawing it through two chilled water sprays, then passing it through eliminator plates where excess moisture is removed.

The idea of conditioning the air blast to a furnace was first recorded about 1880 when attempts were made to regulate the moisture content of the blast by passing the air through calcium chloride, sulphuric acid and other chemicals. In 1890, James Gayley, a blast furnace operator at Pittsburgh, began his experiments using refrigeration to reduce the moisture. This led to the basic concept that the removal of water vapor from the blast would afford definite economies in coke and increase the output of the furnace. Gayley was granted certain basic patents but they have long since expired.

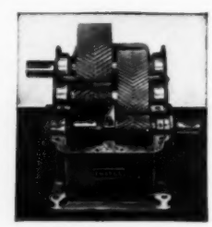
During the first quarter of the century some nine installations were made. The equipment was cumbersome and required a huge capital investment, but the results proved that iron quality could be improved with a saving of coke and limestone by removing water vapor from the blast. The equipment, however, was not dependable and it was difficult to operate, due in part to the formation of tons of ice on the air cooling coils. All of these plants were finally dismantled.

The first modern installation was made by the Woodward Iron Company at Woodward, Alabama, in the summer of 1939. It uses equipment to condense the moisture by cooling with direct sprays of chilled water. These sprays are cooled by a centrifugal refrigeration machine of 500 tons capacity, which is similar to the one being installed by Jones and Laughlin Steel Corporation. The American Rolling Mill Company, at Ashland, Kentucky, installed a chemical system of removing the moisture from the blast. Naturally, furnace operators in the South have a greater concern with air blast moisture content because the average humidity is higher for a greater number of days of the year than in the North.

Woodward Iron Company, as a result of increased output and lowered production costs arising from the installation of air conditioning in the first blast furnace, recently installed a system in a second blast furnace. It was also recently announced that a contract for air conditioning a third blast furnace at Woodward had been let. In awarding the third contract

Group of twenty speed change reducing units

FARREL GEAR UNITS



Typical double reduction assembly. Intermediate bearings and shaft properly proportioned for loads transmitted. Note rigid mounting of high speed pinion.

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A complete series of these units is available for a wide range of industrial applications. It includes single, double and triple reduction units, speed change units having two or more selective speeds, speed increasing units, right angle units, heavy duty drives and drives to meet special requirements.

All units are self-contained and totally enclosed—standardized in general design but with flexibility in detail which permits variation to suit specific conditions of speed, load and service.

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FARREL SYKES GEARS — The Gear with a Backbone

the company stated that air conditioning had increased the pig iron output of the two furnaces by 10 per cent. At the same time, the coke requirements of the furnaces were reduced by approximately 200 lb. per ton of pig iron.

INCREASED ARMOR PLATE CAPACITY FOR CARNEGIE

▲ Carnegie-Illinois Steel Corporation plans to install equipment for production of armor plate in the tin mill of the Farrell Works, thus relieving the pressure on the company's armor plate division. The work at Farrel will be fabrication of the plate.

Heat treating facilities to handle armor plate are now being installed in the Mingo Junction, Ohio, plant of the company as well as at Homestead Works. In addition, new equipment is being installed at the U. S. Navy plant at South Charleston, West Virginia, which is being operated by the Carnegie-Illinois Steel Corporation.

IMPROVED DESIGN FOR RADIATION PYROMETER

▲ A new and improved "Radiamatic" pyrometer designed to operate under severe conditions of temperature and vibration has been introduced by the Brown Instrument Company. The new pyrometer is completely self-contained and compensated for ambient temperature errors. The detector is sighted on the hot object, moving or still, and continuously measures and controls the desired temperature of the material iteslf.

Consisting essentially of a heat-resisting lens, a compensator and a thermopile, the radiamatic operates in the following manner: the heat radiated from the hot object falls on the lens and is focused on the thermopile, which generates an emf. proportional to the true temperature. The compensator corrects for ambient temperature fluctuations surrounding the detector, hence the desired emf. alone developed by the thermopile is translated into degrees of temperature and is continuously indicated, recorded or controlled by the potentiometer.

The new pyrometer is used for those applications where vibration breaks the conventional type thermocouples, where furnaces move or rotate, where work moves or thermocouples cannot be installed, where temperature is above thermocouple range, where furnace atmosphere conditions are unfavorable, or where maintenance of platinum thermocouples is costly.

COPPERWELD CONSTRUCTS TWO ELECTRIC FURNACES

▲ Copperweld Steel Company has announced that construction is well under way on one additional 25 ton and one additional 10 ton top charging electric furnace at the company's Warren, Ohio, alloy steel plant. Upon completion of these two new furnaces in January, 1941, the company will have in operation three 25 ton furnaces and one 10 ton furnace for the production of all grades of alloy steels.

The company had recently added two additional heat treating furnaces, bringing the total heat treating capacity up to 1200 tons per month, and two additional annealing furnaces bring annealing capacity up to 3000 tons per month.

DEVICE OFFERS REMOTE CONTROL OF OIL FLOW

▲ A new pressure sight feed oiler especially designed to permit regulation and observation of oil flow from a point remote from the bearing being lubricated has been developed by the S. F. Bowser and Company, Inc. By installing it in a convenient place, the operator can readily regulate the amount of oil delivered to out-of-the-way or elevated bearings from points remote or below, and by noting the position of the indicating plunger can tell at any time the approximate amount flowing to the bearing.

The important features for this new oiler are as follows: body of wrought steel finished in black enamel with polished, nickel-plated trimmings; needle valve adjustment; capacity ¼ pt. to 1 qt. per min.; adjustable snap rings for indicating amount of oil flow. These oilers are available with ¼ in. or ⅜ in. tapped connections and the maximum working pressure is 50 lb.

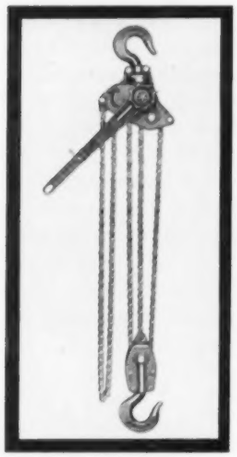
AMERICAN AIR FILTER DENIES MERGER RUMOR

▲ The American Air Filter Company announces that notices of its purchase by a large electrical manufacturing company, as published in several trade and newspaper notices, were premature. Negotiations, which never advanced beyond the preliminary stage, have been definitely abandoned by mutual consent of both companies. There has been no change in ownership, management or field representation of the American Air Filter Company, which will continue to function as an entirely independent organization.

ANNOUNCE ADDITION TO PORTABLE HOIST LINE

▲ A new addition to the line of "Pul-Lift" portable hoists has been announced by the Yale and Towne Manufacturing Company. The new hoist has a capacity of 4½ tons so that now "Pul-Lifts" may be had in a complete range from ¾ to 6 ton capacities. The intermediate sizes have capacities of 1½, 3, and 4½ tons. The new 4½ ton hoist has the same safety and construction features as the previous models. It is light in weight (about 75 per cent less than conventional equipment), making it easily portable, yet is strong and rugged enough to more than adequately care for the jobs within its rated capacity. The great strength combined with the lightness of weight is due to the use of new type alloy steels. The roller chain used in these hoists is specially designed and has an ultimate strength nearly five times the rated capacity of the hoist.

Another feature of this hoist is that



it will operate equally well in horizontal or vertical position. Thus it can be used for both pulling and lifting, and is ideal for almost any type of maintenance job. The "Pul-Lift" also features the famous Yale safety hooks. In case of severe overload, these hooks open slowly, without fracture, giving ample visual warning of danger and positive protection to the operator, the load and the mechanism.

For operation in close quarters and tight out-of-the-way places, this new hoist has a ratchet handle with a universal action. Short, easy strokes at any point within a complete circle permit operation in the most cramped of quarters. Possibility of flying handle is decreased to a minimum by the self-actuated load brake. As the load is increased, brake pressure increases in direct proportion.

MODERNIZED BAR MILL COMMENCES OPERATIONS

▲ Bethlehem Steel Company has started operations at its $4,500,000 bar mill additions at the Lackawanna Works. The addition comprises six connecting buildings located in the town of Hamburg, New York. The buildings are equipped with the latest type furnaces, temperature and pressure controls, and bar-cooling apparatus. The addition replaces the old No. 6 12 in. bar mill.

One of the advantages resulting from the improved and relocated mill is the elimination of a bottleneck in the finishing department. The new mill can operate two or three shifts. The new structures contain 404,000 sq. ft. of floor space, 228 motors furnishing an aggregate of more than 9000 hp., and 13 cranes. The improvements are expected to enable better service to the automotive and other bar-consuming industries in the lakes area.

STARTER PROTECTED FROM ATMOSPHERE

▲ Featuring ease of installation and better protection against corrosion, a new oil-immersed combination a-c. starter, has been developed by the General Electric Company, for use in corrosive or hazardous gas locations. The device is available in two forms—with or without a circuit breaker—depending upon the application. To facilitate installation, a one-piece cast-iron head, used in both forms, permits conduit entrance from five directions. As protection against external corrosion, stainless steel and Monel metal are used for all exposed parts; a copper-bearing steel tank and the cast-iron head provide additional protection. Reversible tips prolong contact life and protection against harmful overloads is supplied by an isothermic induction-temperature relay immersed in the oil.

Where requirements call for explosion-proof control, the device is furnished with an extra-deep tank so that all operating parts are at least 6 in. beneath the surface of the oil. In this type of enclosure, a heavy glass bull's-eye is located in the front of the tank so that the oil level can be easily ascertained.

Where other provisions have been made for short-circuit protection and disconnecting, a circuit breaker is not included with the control. Where such protection is needed, however, the breaker supplied is a new type, rated at 10,000 amperes interrupting capacity and specifically designed for operation under oil. For extra safety, the handle of the circuit breaker is interlocked with the tank so that the breaker must be open before the tank can be lowered. This prevents possibility of lowering the tank while the starter is energized. The handle of the breaker can also be padlocked in either ON or OFF positions to prevent unauthorized operation. To protect an operator from coming in accidental contact with power lines, incoming lines are inclosed in insulating ducts.

ENVIABLE SAFETY RECORD IN CHEMICAL LABORATORY

▲ Carnegie-Illinois Steel Corporation's chemical laboratory at the Gary Works has completed eleven consecutive years without a lost-time accident. The eleven year period covers more than 2,000,000 man-hours completed without an accident.

Among the tasks performed during the achievement of the record were sampling of every tapping of a blast furnace during the casting period, continuous work in control laboratories on the open hearth furnace floors, over seven million quantitative analyses entailing the use of highly concentrated mineral acids, and sampling thousands of carloads of raw materials as well as every cargo of iron ore and limestone received in lake vessels.

NEW ERASING MACHINE FOR DRAFTING ROOM

▲ Embodying an entirely new "core feed" principle which brings to electric erasing machines the convenience of an automatic pencil, a new electric hollow shaft eraser has just been announced by the Charles Bruning Company, Inc. In order to overcome the frequent changing necessitated by short "stubby" eraser tips previously used on erasing machines, the new electric uses an eraser 7 in. long, fitting into a tubular armature shaft. This long, cylindrical rubber core can be fed out as it wears down and tightened at the lower end of the instrument by a chuck.

The motor unit of this erasing machine is especially designed for the machine, and has an impeller-type fan mounted on the shaft within the strong light-weight die-cast aluminum motor housing, insuring cool operation. A precision ball bearing at the chuck end assures long, trouble-free operation with a maximum of quietness.

Operation of the machine is greatly simplified by the convenient sliding control button, designed to fit under the index finger. When the button is slid forward, the machine remains in "on" position if continuous operation is desired. The body of the machine is designed for convenient holding in the hand.

IN TIMES LIKE THESE

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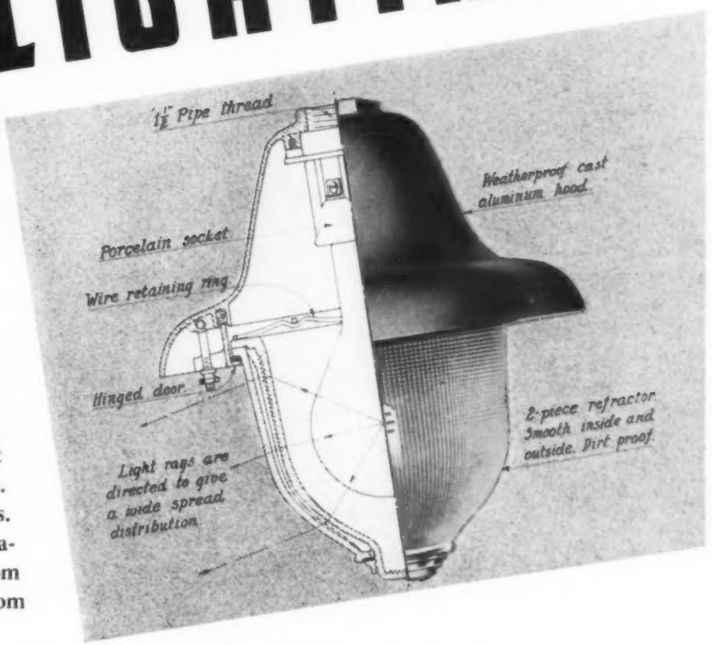
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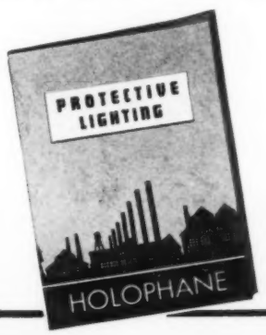

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ITEMS OF INTEREST

E. E. Moore has been elected vice-president, industrial relations, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania, succeeding D. A. Barrett, retired. Mr. Moore has been associated with the United States Steel Corporation subsidiaries since 1919, when, following completion of his army service in the American Expeditionary Forces, he secured employment as a machinist at the Gary mills of the American Sheet and Tin Plate Company. In 1920 he became foreman of the machine shop there and three years later was transferred to the Pittsburgh office to do special work. Within a short time he was assistant manager of the Shenango Works at New Castle, Pennsylvania. He returned to the Gary tin mill in 1926 as assistant manager in charge of construction and operation of the 42 in. strip mill. In 1932 he became assistant to vice-president of the Illinois Steel Company. When, in 1935, Illinois Steel Company plants became a part of Carnegie-Illinois Steel Corporation, Mr. Moore was appointed general superintendent of the South Works, Chicago, Illinois. Three years later he became general superintendent of its Gary Works, the position he has held until the present time. Mr. Moore is an active member of the Association of Iron and Steel Engineers.

D. A. Barrett, vice-president of industrial relations, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania, retired on December 1, 1940, upon completion of 44 years of service with the corporation and predecessor companies. Mr. Barrett has acted in a supervisory capacity since 1901, when he became hot mill foreman at the former La Belle Works. From 1904 until 1928 he served the American Sheet and Tin Plate Company as superintendent or manager in plants in the Ohio valley and at Vandergrift, Pennsylvania. He became assistant to the vice-president on January 1, 1929, and was elected vice-president on January 1, 1933. When American Sheet and Tin Plate Company became part of the Carnegie-Illinois Steel Corporation in 1936, he was elected vice-president, industrial relations, the position he has held until his present retirement.

S. M. Jenks was appointed general superintendent of the Gary Works, Carnegie-Illinois Steel Corporation, Gary, Indiana, succeeding E. E. Moore. Mr. Jenks, a graduate of Cornell University with a degree of mechanical engineer, has been connected with the United States Steel Corporation subsidiaries since 1925, when he began in the engineering department of the American Sheet and Tin Plate Company, after two years' previous experience as a blast furnace blower with the Jones and Laughlin Steel Corporation. He went to the Gary sheet and tin mills in 1929 as a fuel engineer. In 1933 he was transferred to Pittsburgh as power engineer of the company. From 1935 to 1936 he was assistant chief engineer of the company and when the American Sheet and Tin Plate Company became part of the Carnegie-Illinois Steel Corporation, he was made chief engineer of the construction division.

Mr. Jenks returned to Gary, February 1, 1937, as chief engineer of the Gary Works, and remained in this capacity until October 31 of the same year, when he was appointed assistant general superintendent, the position he has held until the present time. Mr. Jenks, who is an active member of the Association of Iron and Steel Engineers, was recently elected to serve as a director on the 1941 board of directors of the Association.

Arthur V. Wiebel was appointed assistant to vice-president, engineering, United States Steel Corporation of Delaware, Pittsburgh, Pennsylvania. Mr. Wiebel, a 1928 graduate in mechanical engineering from the Carnegie Institute of Technology, joined the Carnegie Steel Company as an engineering estimator in the Youngstown, Ohio, district in 1933. He worked in the Pittsburgh general engineering offices of Carnegie-Illinois Steel Corporation in 1937, and in June, 1938, was appointed assistant chief engineer of the Homestead, Pennsylvania, plant. In March, 1940, he was appointed chief engineer of the Carnegie-Illinois Steel Corporation's Pittsburgh district. Mr. Wiebel is an active member of the Association of Iron and Steel Engineers.

Howard L. Dawson succeeds Arthur V. Wiebel as chief engineer of the Pittsburgh district, Carnegie-Illinois Steel Corporation. Mr. Dawson studied metallurgy and machine construction at the Carnegie Institute of Technology. He was first employed as a draftsman at the Edgar Thomson plant in 1912, and later became, in turn, efficiency engineer, construction engineer, master mechanic, and maintenance superintendent. Until recently he has served on the engineering staff as engineer, in charge of repairs, maintenance, and lubrication for the Carnegie-Illinois Steel Corporation with his headquarters in Pittsburgh. Mr. Dawson is an active member of the Association.

C. H. Williams has been appointed assistant chief engineer, Pittsburgh district, Carnegie-Illinois Steel Corporation. Mr. Williams was graduated from the University of Colorado, College of Engineering, in 1926. He was employed by the Jones and Laughlin Steel

E. E. MOORE

S. M. JENKS

ARTHUR V. WIEBEL

C. H. WILLIAMS

E. A. BROW

Corporation, South Side Works, Pittsburgh, Pennsylvania, as shear foreman in September, 1926. In June, 1927, he was junior engineer in the power engineering department of the National Tube Company, in the Pittsburgh plant. In April, 1930, Mr. Williams joined the Carnegie Steel Company, Youngstown district, as junior engineer in the steam engineering department. He successively served as power and fuel engineer and assistant chief engineer of the Youngstown district. In August, 1940, he was transferred to the Pittsburgh office of the Carnegie-Illinois Steel Corporation as power and fuel engineer on the staff of the chief engineer.

Mr. Williams was appointed assistant chief engineer, Carnegie-Illinois Steel Corporation, Pittsburgh district, in December of this year. He was recently elected to serve on the 1941 board of directors of the Association of Iron and Steel Engineers.

E. A. Brown, Jr., was appointed superintendent of the power and fuel division of the Carnegie-Illinois Steel Corporation's Gary Works. Mr. Brown, who has been in the industrial engineering field for the past thirty years, was superintendent of the fuel division at the time of his recent appointment.

F. L. Collins was appointed assistant superintendent of the power and fuel division of the Gary Works, Carnegie-Illinois Steel Corporation. Mr. Collins has been superintendent of power production in the maintenance division and has been associated with the Gary plant since 1909.

Leonid A. Umansky was appointed assistant manager of the industrial engineering department of the General Electric Company, Schenectady, New York. Mr. Umansky was born July 23, 1890, in the Province of Don, Russia. He was educated at the Polytechnic Institute of Petrograd, where he studied electrical and mechanical engineering and was graduated in 1915. He joined the Schenectady Works of the General Electric Company in February, 1919, as a test man. In November 1920, he was transferred to the power and mining engineering department, and remained with this department, through its transition to the present industrial engineering department, until 1931. In March, 1931, Mr. Umansky was transferred to the International General Electric Company and took up work in Russia. He returned to the industrial engineering department of General Electric in 1933.

Francis Mohler has been appointed engineer of the steel mill section, General Electric Company, Schenectady, New York. Mr. Mohler, the new engineer of the steel mill section, was born in Rockbridge, Virginia, October 20, 1903. He was educated at the Virginia Polytechnic Institute, where he studied electrical engineering and was graduated in 1926. He joined the General Electric Company as a test man in July, 1926, and was transferred to the industrial control engineering department in July, 1928. In 1929 he joined the steel mill section of the industrial engineering department.

Frank E. Flynn, manager for Republic Steel Corporation, in the Warren-Niles, Ohio, district was elected president of the Trumbull Manufacturers' Association, Youngstown, Ohio.

William C. Hogg has been appointed assistant to general superintendent, Homestead Works, Carnegie-Illinois Steel Corporation. Mr. Hogg previously was assistant superintendent of open hearth departments at the Homestead plant. He was born at Pittsburgh in 1904, attended public schools there, and received preparatory training at Phillips Academy. He was graduated from Sheffield Scientific School, Yale University, in 1925.

Mr. Hogg entered the steel industry as a laborer in the open hearth department at the Homestead Works in July, 1925, and his steel making experience subsequently included service as cinder pitman, second helper, melter foreman, foundry furnace foreman, labor foreman, assistant superintendent and departmental superintendent. He was appointed assistant superintendent of open hearth departments June 1, 1940, and became assistant to general superintendent, December 3, 1940.

Forman H. Craton has been appointed section head of the industrial haulage section of the General Electric Company's transportation department at Erie, Pennsylvania. Mr. Craton has been with the General Electric Company since 1924, when he joined the company's factory management course at Schenectady after being graduated from Syracuse University with the degree of mechanical engineer. Following this he was a member of the regular testing course.

After about four years' work on the design of railway motors and control, Mr. Craton was transferred to the transportation commercial engineering department.

Dundas Simpson has been appointed superintendent, masonry department, South Works, Carnegie-Illinois Steel Corporation, Chicago, Illinois. Mr. Simpson went to the South Works as a mason foreman

E. A. BROWN, JR.

F. L. COLLINS

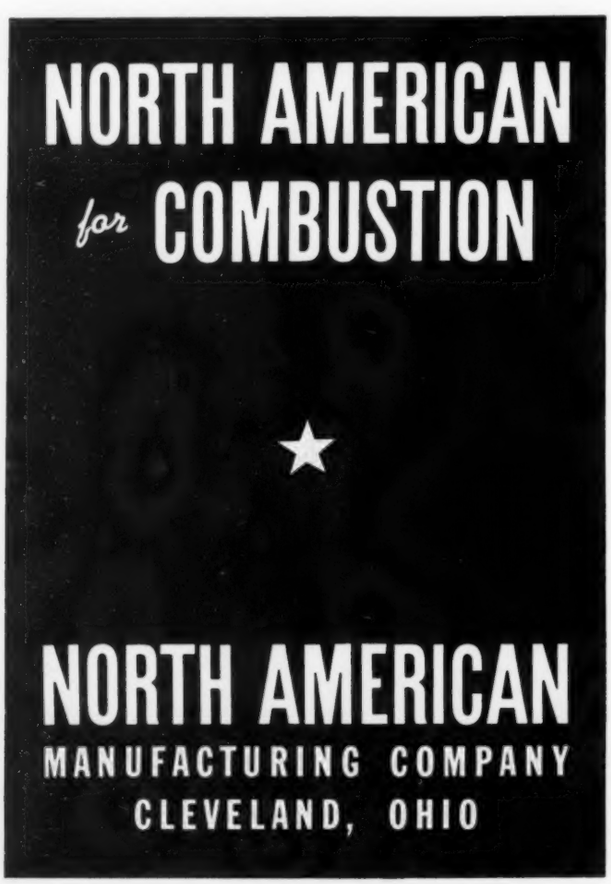
L. A. UMANSKY

F. MOHLER

in 1917 after many years of experience with various contractors. From 1929 to 1931, during the construction of the 54 in. beam mill, the 44 in. slab mill and the No. 4 open hearth furnace, he served as temporary assistant superintendent of the masonry department. He has been assistant superintendent of this department since July, 1937.

Bennett Lodge has been appointed general superintendent of the River Road plant of Wickwire Spencer Steel Company at Buffalo, New York. Mr. Lodge has been with the Buffalo plant for many years and succeeds George W. Nelson, who, with Paul M. Macklin, was drowned during a hunting trip in Maine on November 7. No successor has been appointed to Mr. Macklin, who had offices in New York.

J. E. Bowen has been appointed general manager of the Stran-Steel division of Great Lakes Steel Corporation. In 1929 as representative of McClintic-Marshall Company, he was in charge of structural design in the construction of the original Great Lakes plant. In 1930 he became superintendent in charge of erection of steel structure for the Philadelphia and Reading Railroad. In 1933 he was associated with Gibbs and Hill, consulting engineers, New York, where he remained until 1935, when he returned to Great Lakes, assisting in the design of plant expansion. In 1937 he was appointed chief engineer of the Stran-Steel division and promoted to assistant manager this year. Mr. Bowen is a member of the Association of Iron and Steel Engineers.



Edward A. Phoenix, assistant sales promotion manager in charge of industrial products, Johns-Manville Sales Corporation, New York, New York, was honored recently when he was made a member of the Johns-Manville Quarter Century Club, honor society of the company's employees with 25 or more years of service. The occasion was marked by a luncheon at the Hotel Commodore, in New York, when Mr. Phoenix was presented with a gold watch.

E. H. Mebs, metallurgist of the Ohio Steel Foundry Company, Lima, Ohio, for the past ten years, has resigned to accept a position with the United States Steel Corporation.

Frank Oppenheimer, formerly chief engineer, Apollo Steel Company, Apollo, Pennsylvania, was recently appointed general superintendent, succeeding the late Howard C. McGaughey.

H. T. Lintott was appointed manager of industrial relations for the Columbia Steel Company, subsidiary of the United States Steel Corporation, at San Francisco, California. Mr. Lintott succeeds E. M. Stephens, who has been on temporary assignment as manager of industrial relations since 1939.

Otto A. Kresse succeeds H. T. Lintott, as chief of the Torrance, California, plant of the Columbia Steel Company, subsidiary of the United States Steel Corporation.

Clarence L. Taylor, formerly vice-president in charge of engineering for the Aetna-Standard Engineering Company, has been elected vice-president in charge of engineering for Arms-Franklin Corporation of Franklin, Pennsylvania. Delmont Calladine, formerly superintendent of the Warren, Ohio, plant of the Aetna-Standard Engineering Company, and later superintendent of the Taylor-Winfield Corporation, was recently appointed manager of operations for the Arms-Franklin Corporation.

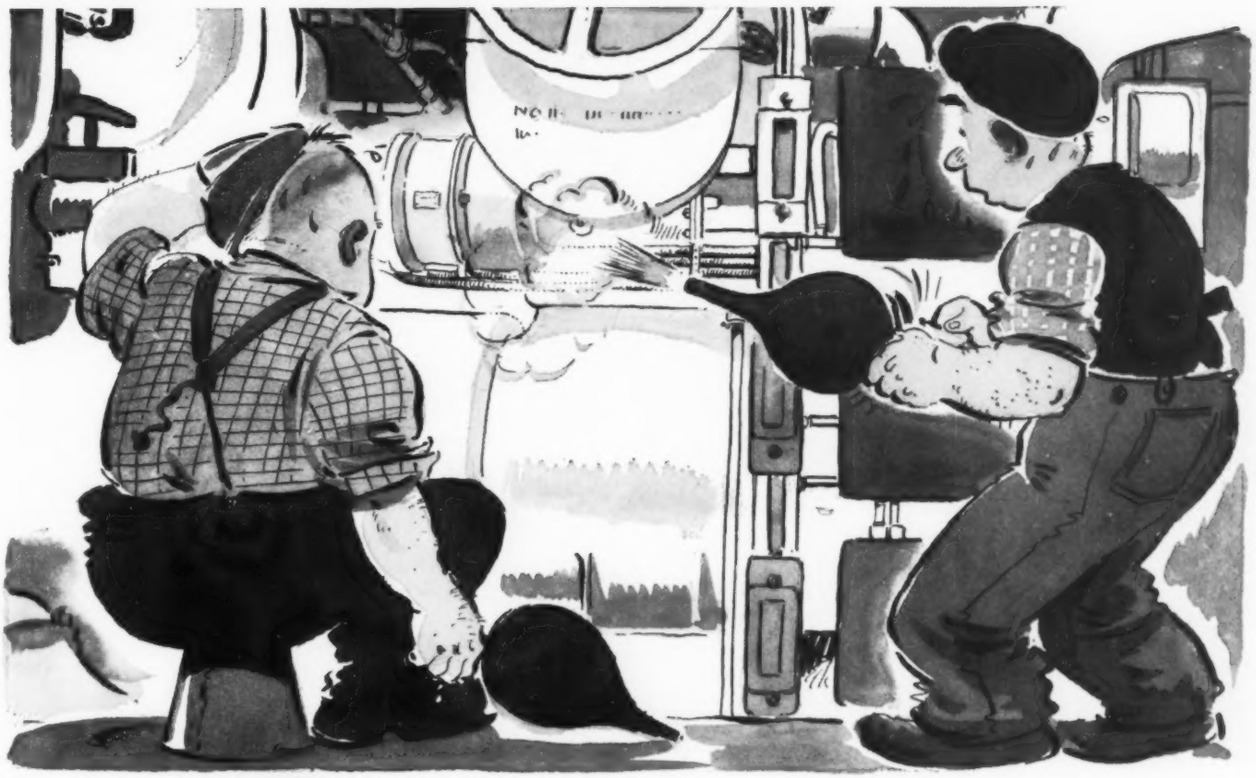
L. R. Kells, heretofore chief engineer of the Salem Engineering Company, Salem, Ohio, has been placed in charge of the furnace department of the Wellman Engineering Company, Cleveland, Ohio. He has had extensive experience in the design and sale of furnaces and has been associated with the Mt. Vernon Bridge Company, Chapman Engineering Company, Surface Combustion Corporation, and Askania Regulator Company.

E. A. Hurme, formerly connected with the Clark Controller Company and Westinghouse Electric and Manufacturing Company, has been appointed Chicago district manager for Crocker-Wheeler Electric Manufacturing Company.

Obituary

Edwin Lee Upp 70, formerly superintendent of the electrical department of the National Tube Company' McKeesport, Pennsylvania, died December 3. Mr. Upp worked for the National Tube Company for more than 32 years, located at various times in Lorain, Ohio, and Gary, Indiana. Mr. Upp had been an active member of the Association of Iron and Steel Engineers since 1916.

C. W. (Neal) Roy, employed as a sales engineer for the National Electric Products Corporation, died December 2.



Take a HOT TIP

Sure, this is one way to prevent heat from pulverizing the insulation on wire running close to boilers, steam lines, lehrs, soaking pits, furnaces or other hot spots . . . but the boys *might* let up on the bellows and it doesn't seem practical anyway. Not when you can handle the situation with ROCKBESTOS permanently insulated wires that are built to take heat and just about everything else that will ruin ordinary wire.

When you install ROCKBESTOS asbestos insulated wires, cables or cords you are getting rid of the principal cause of wire failure . . . insulation breakdown . . . and you are making certain that your first cost will be your only cost. Better than that, in addition to saving the repeated expense of replacing short-lived wiring, you are eliminating wasteful current leakage, possibility of short circuit fires and assuring uninterrupted service which is even more important just now.

You'll find proof of our claims in every one of the 118 different wires and cables in the ROCKBESTOS line because they all have these service-guaranteeing features: They won't dry out because their insulation is heatproof . . . they won't burn or support flame because their insulation is fireproof . . . they won't rot, bloom or swell because their insulation is resistant to alkalies, grease, oil and corrosive fumes . . . and they were all designed to meet severe operating conditions in specific applications and have proven their ability to do so *effectively, economically* and *permanently*.

Our No. 10-E Catalog shows a complete line of money-saving permanently insulated wires, cables and cords. Send for it today. Rockbestos Products Corporation, 978 Nicoll St., New Haven, Connecticut.

TEN TESTED ROCKBESTOS VALUES

1. HEATPROOF
2. FIREPROOF
3. PERMANENT
4. Lower maintenance cost
5. Resists heat and vibration
6. Saves work
7. Oil, Grease and Moisture resistant
8. High overload capacity
9. Permanently flexible
10. Greater carrying capacity

Also refer to the Electrical Contracting and Electrical World Buyer's Reference Editions

New York Buffalo Cleveland Detroit Chicago
Pittsburgh St. Louis Los Angeles San Francisco Portland, Ore. Seattle

A typical construction — Rockbestos A. V. C. 600 volt Power Cable, Table E — one of 118 different permanently insulated wires and cables

NATIONAL CARBON GRAPHITE KARBATE PRODUCTS

TRADE-MARK

TRADE-MARK

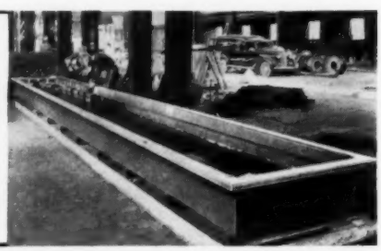
Reduce Losses

FROM CORROSION, THERMAL SHOCK AND CONTAMINATION OF PRODUCT

● Carbon, Graphite and "Karbate" products are highly resistant to the action of most acids, alkalies and other corrosive liquids and gases. They possess good mechanical strength and exceptional resistance to thermal shock.

"Karbate" is a brand of material, of carbon or graphite base, which is impervious to the seepage of fluids under pressure. Graphite and "Karbate" No. 2 have high thermal conductivity and excellent heat transfer properties.

CONSTRUCTION MATERIALS

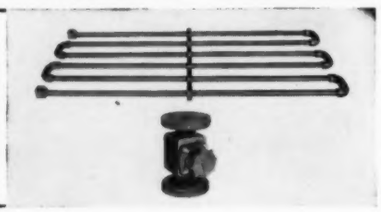


Carbon and Graphite Brick, Flat Tile, Blocks, Beams and other structural shapes are used for the construction or lining of many types of processing equipment because of their high resistance to corrosion and their ability to resist the destructive effects of severe thermal shock. Graphite construction materials are used where high thermal conductivity is needed.

Carbon is used with excellent results for lining

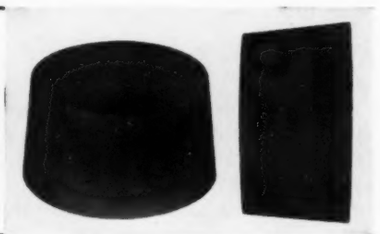
PICKLING TANKS • DESULPHURIZING LADLES • BLAST FURNACES

PIPE, VALVES AND FITTINGS



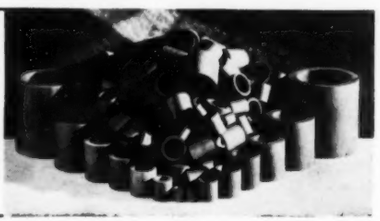
Carbon, Graphite and "Karbate" pipe and fittings are available in sizes from ½ inch to 6 inches I.D. Saunders type valves of "Karbate" construction are also available. These corrosion resistant products are used for the construction of drain lines, heating coils — both steam and gas-flame types, and other types of conveying, circulating and heat exchange equipment. Carbon or "Karbate" No. 1 is recommended where high heat transfer properties are not desired. Graphite and "Karbate" No. 2 pipe have heat transfer properties equal to steel pipe of corresponding I.D. Plain Carbon and Graphite pipe and fittings are sufficiently impervious to convey fluids at low pressure without disturbing seepage. Graphite pipe heat exchangers are being used to heat corrosive baths with low pressure steam and eliminate the dilution resulting from injection of steam in the bath. At higher pressures, or where all seepage must be prevented, "Karbate" materials are recommended.

CARBON INGOT MOLD PLUGS



The use of Carbon Mold Plugs in alloy steel ingot molds eliminates ceramic inclusions and resulting loss of ingots. It also prevents contamination of the scrap obtained from the cropped ingot ends. With correct use, carbon plugs can each be used for several pourings.

CARBON RASCHIG RINGS



Carbon Raschig Rings provide an efficient and economical packing material for gas scrubbing towers. They are mechanically strong and highly resistant to both the thermal shock and the corrosive materials encountered in this service. Their low weight per unit of volume reduces cost of tower construction.

OTHER PRODUCTS OF VALUE TO THE IRON AND STEEL INDUSTRY

- Graphite Crucibles and Molds
- Carbon Powder to prevent piping of hot tops
- Graphite Powder for mold wash
- Graphite Powder for lubrication

Write FOR COMPLETE INFORMATION ON THE PRODUCTS IN WHICH YOU ARE INTERESTED

NATIONAL CARBON COMPANY, INC.

Unit of Union Carbide and Carbon Corporation

UCC

CARBON SALES DIVISION, CLEVELAND, OHIO

General Offices: 30 East 42nd Street, New York, N. Y.

BRANCH SALES OFFICES

NEW YORK • PITTSBURGH • CHICAGO • ST. LOUIS • SAN FRANCISCO

TRUMBULL STYLE "A"

INDUSTRIAL SAFETY SWITCHES

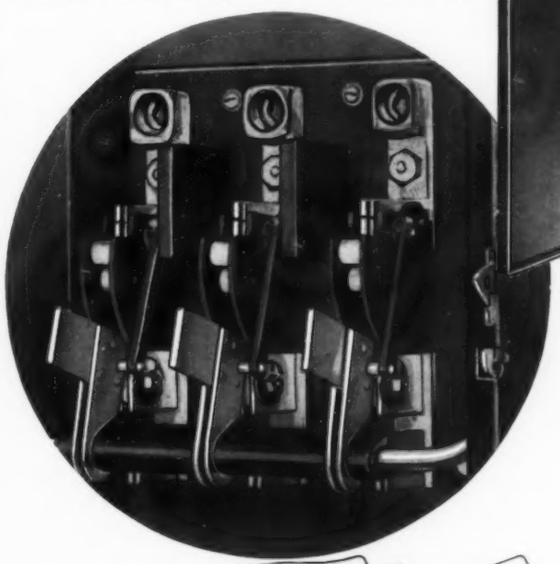
FOR HEAVY DUTY MILL SERVICE

For more than 40 years this pioneer line has been serving Industry . . in the beginning as open knife switches, later in switch boxes and finally in the externally operated safety enclosures we know today.

Nor is it only in length of service that Style "A" (Type "A") is properly called the PIONEER LINE. For this was one of the FIRST Safety Switches to be equipped with INTERLOCKING COVER . . . one of the FIRST to have QUICK-MAKE, QUICK-BREAK mechanism . . . the FIRST to have ARC QUENCHERS (Snuf-Arcs) and to be given the approved HORSE POWER RATINGS made possible by Snuf-Arcs.

Steel mill electrical engineers find in Trumbull Style "A" Safety Switches those qualities of year-round dependability, true heavy duty construction and easy accessibility for inspection, so essential in this field.

Write for Trumbull Style "A" Circular No. 392



RECENT DEVELOPMENTS

"U" shaped insulating FIBRE CROSS BAR prevents arcing through dust accumulation on yoke . . a safeguard against grounding of switch parts in case of overload. Lacquer finish prevents absorption of moisture.

VYSTIPE FUSE CLAMPS eliminate excessive heating at fuse contacts. Equipped with SOLDERLESS LUGS.

NEW Safety COVER CATCH withstands heavy pressure.

Can be locked in "on" or "off" position (3 padlocks).

Releasable interlock for examining switch under load.

Entire mechanism front mounted on single base. Easily removable and inspectable.

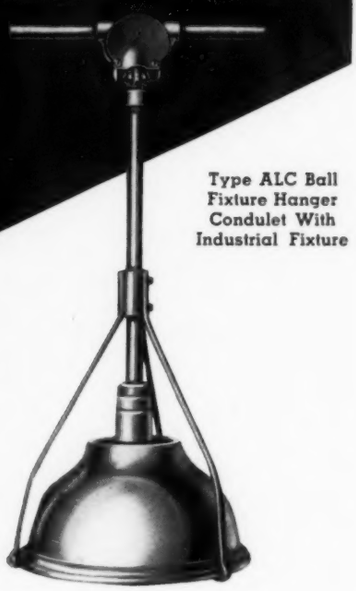
ESTABLISHED 1899 — THE TRUMBULL ELEC. MFG. CO. — PLAINVILLE CONN. U.S.A. — A GENERAL ELECTRIC ORGANIZATION

Trumbullaids for Steel Engineers

The Trumbull Products shown in these advertisements are illustrated, described and listed in the Trumbullist, in individual circulars and in Trumbull 'Cheer'. Be sure your name is on our lists to receive all of these important TRUMBULLAIDS

NEW YORK - PHILADELPHIA - BOSTON - CHICAGO - DETROIT - LUDLOW, KY. - ATLANTA - NASHVILLE - LOS ANGELES - SAN FRANCISCO - SEATTLE

CROUSE-HINDS
Flexible Fixture Hangers



Type ALC Ball Fixture Hanger Condulet With Industrial Fixture

Type ALC With Connection Block, Cover Removed

Type ALC Ball Fixture Hanger Suspended on Horizontal Cable

Type ALD Ball

Type ALC Cushion

Type UNJ Ball — Type UNJC Cushion

Type AHG Cushion

Type UNH Hangers

Type GS Ball

Type UNE Loops

Pendent fixtures in industrial occupancies usually are of such length that unless guyed or flexibly supported, the upper stem fastening may be broken by strains due to winds or accidental impact.

Guying is inconvenient, unsightly, and in many cases, impractical. Furthermore, flexible attached fixtures always hang plumb. Flexible mountings also permit the use of cushion supports relieving the lamp filaments of vibrations, thereby prolonging lamp life.

The Crouse-Hinds Company has hangers suitable for all ordinary and many extraordinary requirements.

The AL series is applicable to any exposed conduit installation. A terminal block makes for easy installation and removal. The AL series can be furnished with a malleable iron fitting fastened to the top of the Condulet for direct attachment to a messenger wire or to a rod suspended from a messenger wire or ceiling.

The type ALD hanger has through feed hubs set at an angle and is for use where the supporting surface is not horizontal, as in sawtooth roof construction.

The types UNJ and UNJC hangers are designed for attachment to the hubs of Condulets. These hangers are compact in form and inconspicuous when installed.

The type AHG hangers are vaportight and should be used wherever it is necessary to prevent steam or vapor from entering the conduit system or fixture. The hanger may be attached to the hub of any suitable Condulet. This hanger is made in cushion style only

The type GS hangers are for attachment to the GS series Condulets. This combination is watershedding and should be used in locations where the walls are washed by a hose stream. This hanger is made in the ball style only.

The type UNH hangers and type UNE loops are so designed that accidental disengagement of the parts is eliminated.

CROUSE-HINDS COMPANY
SYRACUSE, N. Y., U. S. A.

Sales Offices: Birmingham — Boston — Chicago — Cincinnati — Cleveland — Dallas — Detroit — Houston — Kansas City — Los Angeles — Milwaukee — Minneapolis — New York — Philadelphia — Pittsburgh — San Francisco — Seattle — St. Louis — Washington

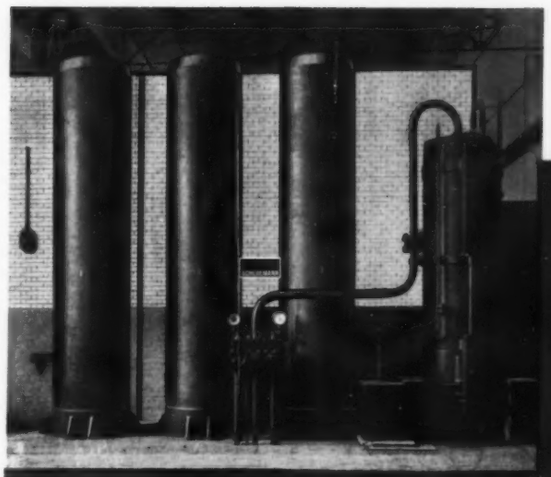
Resident Salesmen: Albany — Atlanta — Baltimore — Buffalo — Charlotte — Denver — Louisville — New Orleans

CROUSE-HINDS COMPANY OF CANADA, LTD.,
Main Office and Plant: TORONTO, ONT.

Condulet Catalog No. 2500 will be sent on request.

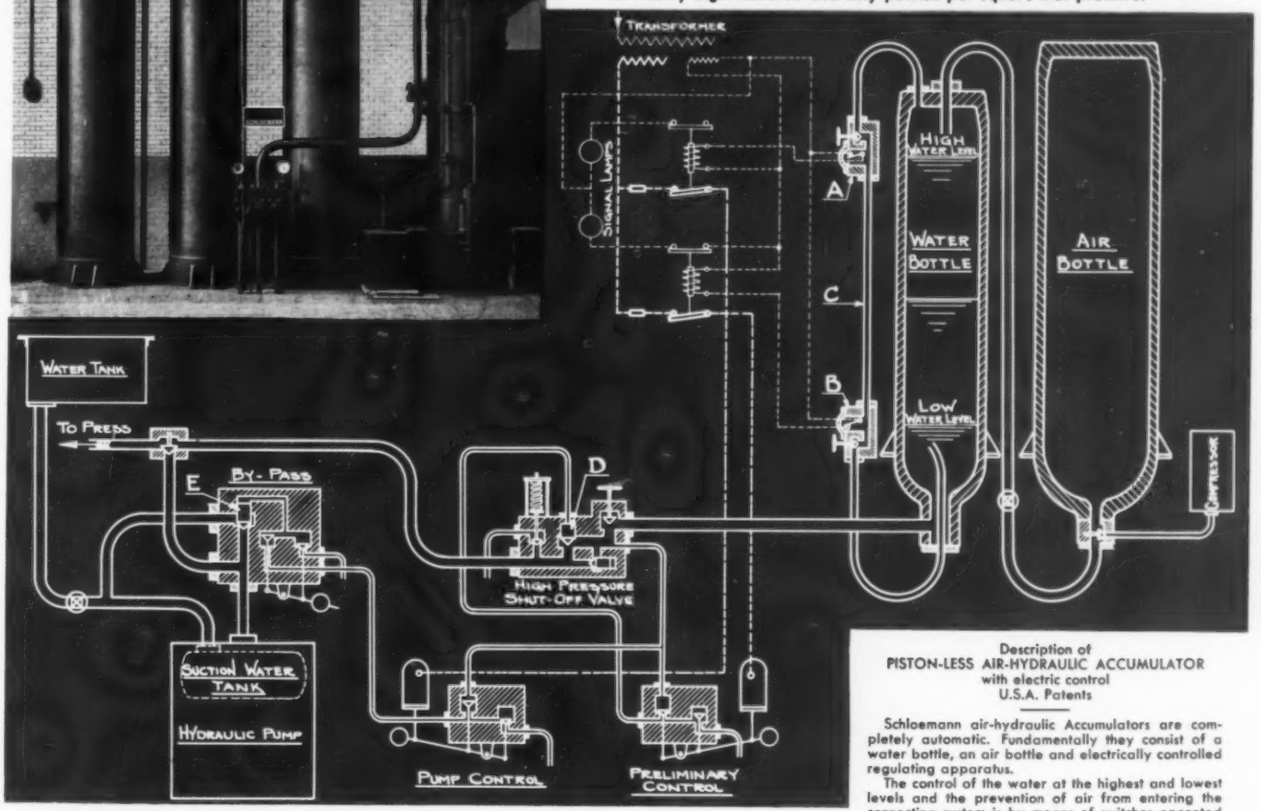
A Nationwide Distribution Through Electrical Wholesalers

C-1682



Accumulators furnished in sizes from fifty gallons to twenty-five hundred gallons and for pressures up to forty-five hundred pounds per square inch.

System shown at left has two hundred gallons capacity and is designed for twenty-eight hundred and fifty pounds per square inch pressure.



Description of
PISTON-LESS AIR-HYDRAULIC ACCUMULATOR
with electric control
U.S.A. Patents

Schloemann air-hydraulic Accumulators are completely automatic. Fundamentally they consist of a water bottle, an air bottle and electrically controlled regulating apparatus.

The control of the water at the highest and lowest levels and the prevention of air from entering the connecting system is by means of switches operated by floats contained in chambers of a communicating tube "C." Thus the switch "A" in the upper chamber controls the operation of the hydraulic pump, while that in the lower chamber "B" controls the check valve "D" which shuts off the accumulator at lower water level.

The continuous running pump is controlled by closing the By-Pass check valve "E" by means of the pump control, causing it to idle by opening the same and returning the water to the suction end. Over-pressure is released through safety valves and is indicated by an alarm.

SCHLOEMANN

AIR-HYDRAULIC ACCUMULATORS

HYDRAULIC EXTRUSION PRESSES

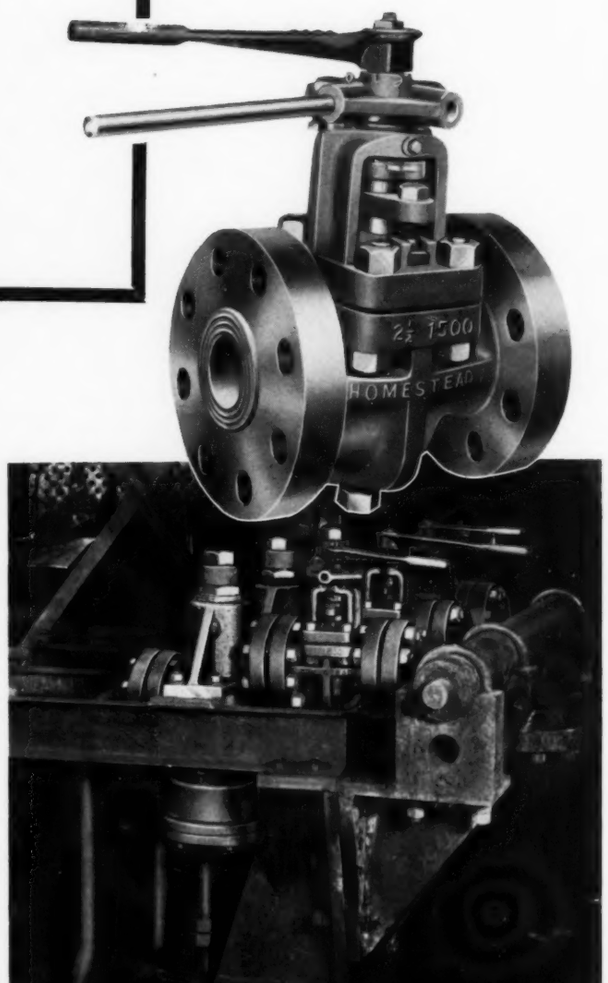
HIGH PRESSURE PUMPS

COMPLETE HYDRAULIC SYSTEMS

SCHLOEMANN

ENGINEERING CORP. PITTSBURGH, PA.
Rolling Mill Machinery Hydraulic Presses

Your Valve Troubles END with HOMESTEAD *Lever-Seald* PLUG VALVES!



YOU can bet on these six "built-in" features of Homestead Lever-Seald Valves to put a quick stop to valve troubles:

- *Quarter-turn* fully opens or closes.
- *Instant, easy operation* by powerful leverage. Cannot stick.
- *No leakage.* Deep stuffing box. *Minimum upkeep.*
- *Long, low-cost service.* Seating surfaces protected in open and closed positions.
- *Positive leakless seal* . . . no lubrication required.
- *Minimum pressure drop* . . . straight line flow.

Installation of 2½" Lever-Seald Homestead Valves on 1500 pounds W.P. hydraulic stop service, in a large Mid-Western Steel Mill. Direct air operated Homestead Protected Seat Spray Valves for the descaling system are also shown.

Homestead Lever-Seald Valves are made in a wide range of sizes and types, and cast in steel, iron, stainless steel, bronze, Monel, Ni-Resist, and other metals suitable for the specific temperature, fluid, and pressure conditions.

Choose the proper type for your needs from Reference Book No. 38 (copy sent free on request). Then specify or order Homestead Lever-Seald Valves for your next job.

HOMESTEAD VALVE MFG. CO., BOX 21, CORAOPOLIS, PA.

HOMESTEAD VALVES

QUARTER-TURN VALVES:
STRAIGHT-WAY
THREE-WAY
FOUR-WAY
LUBRICATED TYPE
LIFT-TYPE PLUG

PROTECTED-SEAT VALVES:
HYDRAULIC (R. & O. PAT.) OPERATING
REMOTE CONTROL
HYDRAULIC DESCALING
ROSS AIR SHUT-OFF VALVES
HOVALCO BLOW-OFF VALVES

LEFT: Late model of "midget" fork truck with pallet load elevated for tiering; this truck operates in limited clearances. *ABOVE:* Late model of heavy-duty ram truck handling material in process in steel industry. *RIGHT:* A 30-cell D8 Edison Steel-Alkaline Storage Battery in latest model of demountable steel compartment for use on center-control fork truck; has twice the power and capacity available in 1917 for a compartment of equivalent floor area.

Industrial Preparedness

...Then and Now

☆ AMERICA'S industrial preparedness program during the first world war stimulated a search for more efficient methods of material handling and brought about a very general adoption of the then-new method of handling materials on skid platforms by battery lift trucks.

This method eliminated much former lost motion and needless commodity rehandling, especially between common carriers and process, thus contributing added efficiency to the industrial preparedness efforts at that time.

To aid in the preparedness program of today, the industrial truck industry is again ready; and it offers methods of material handling much more advanced than those available in 1917. As one example, the fork-truck-pallet system—especially since the development of the highly maneuverable center-control fork truck—brings the advantages of power carloading within the reach of virtually every industry.

In most industries, it also affords a means of virtually eliminating all rehandling between process and carriers; and it is the most efficient method yet developed for handling materials during storage.

In the heavy industries, it also affords a highly efficient means of handling materials through process, frequently supplementing and raising the efficiency of older systems.

Contributing to the success of this new system has been the development of improved storage batteries—batteries which provide more power and capacity than ever before in proportion to their length and width. These modern batteries provide the proved advantages of all-electric operation for any industrial truck from the smallest to the largest and for any daily schedule up to 24 hours.

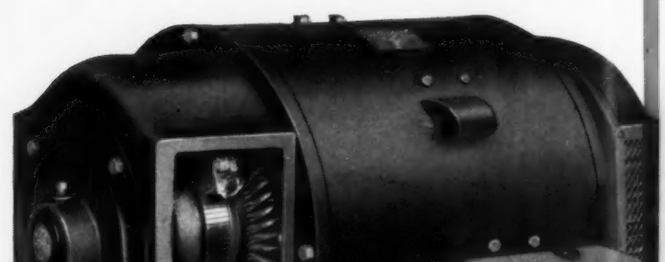
EDISON

STORAGE BATTERY

DIVISION OF THOMAS A. EDISON, INC. WEST ORANGE, NEW JERSEY, U.S.A.

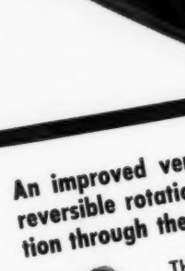
There's DOUBLE P

in the NEW FEATURES ... o



G-E direct-current motor, Type CD, typical of the larger ratings.

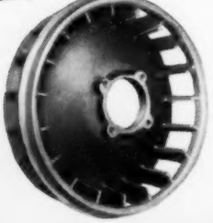
An improved ventilating system, designed for reversible rotation, gives positive axial ventilation through the motor.



The same bearing bracket is used for ball and sleeve bearings, and the bearings can be removed without disturbing brush-rigging connections.

The larger motors have a new "V-type" brush holder designed for reversing service.

Split construction of the highly efficient fan scroll, which forms the drive-end bearing bracket, allows the scroll to be removed easily.



The radial-blade fan is cast-aluminum and specially designed for use in reversing service. The fan is rabbetted and bolted to the armature spider.

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PROTECTION

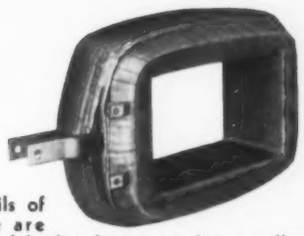
of G-E Direct-current Motors

Exposed Parts Protected against External Damage

The over-all design of the open motor makes it readily adaptable for use even on jobs that have natural hazards to motor life. It not only safeguards the motor parts, but also increases safety for workmen.

Protected Internally against Electrical Failure

Electrical protection is gained through the use of Formex magnet wire in the armatures and field coils, and by a final treatment of a specially developed Glyptal base insulating varnish which gives additional value to the other fine insulating materials used.



Main field coils of Formex wire are wound on spool bodies having insulating collars that insulate coil and pole from frame. Each coil is taped, dipped, and baked. A completed coil is shown above.

OTHER new features of G-E d-c motors include such improvements as cast-aluminum fans specially designed for reversing service; reversal without changing any part of the frame, fan, or brush rigging; compact assembly; more positive ventilation; lower WR^2; small diameter, which means low headroom needed; and interchangeability of ball- and sleeve-bearing brackets on the larger motors.

Main field pole pieces are laminated silicon steel, welded together and securely bolted to rolled-steel frame.

These and additional features which all sum up to increased all-round performance and protection are rolled-steel frames, V-type brush holders, cast-brass brush-holder boxes, accurately centered rabbet fit of precision machining, extra large conduit box, provision for lubricating and flushing of bearing while motor is running, punched commutator segments, Textolite wedges in armature slots for winding protection, and constant air gap.

All current-carrying parts and rotating parts, except shaft extensions, can be enclosed readily for protection of operators.

Commutating coils are made of edgewise-wound copper strip with enamel turn insulation, and are insulated from the pole by a layer of laminated acetate paper.

Surely you will want to learn more about motors with such outstanding improvements. These G-E direct-current motors are being applied in increasing numbers on jobs for which standard designs formerly were not recommended. They are fully fitted to fill the bill on your jobs. Call our local office. General Electric Company, Schenectady, N.Y.

Continuous rabbet fit of rolled-steel frame assures accurate concentricity and alignment of the bearing bracket. Additional insulation protects the basic dielectric strength of Formex wire, and red Glyptal varnish protects the coils.

GENERAL ELECTRIC

QuelArc circuit breaking plugs and receptacles for heavy portable equipment, 2, 3, 4 wire types, 20 to 200 amperes, 250 volts DC, 600 volts AC. Bulletin 1140-2.
Triploc and Multiple Circuit plugs and receptacles for portable tools, instruments and control circuits. Interchangeable contact units permit any combination, 1 to 32 poles. Bulletin 1140-1.
Example of Multiple Unit plug and receptacle assembly with three 4-pole contact units, total 12 poles.
THE PYLE-NATIONAL COMPANY
CHICAGO U.S.A.
General purpose plugs and receptacles, for heavy duty portable tools and equipment, 2, 3, 4, 5 poles. Bulletin 1140-3.

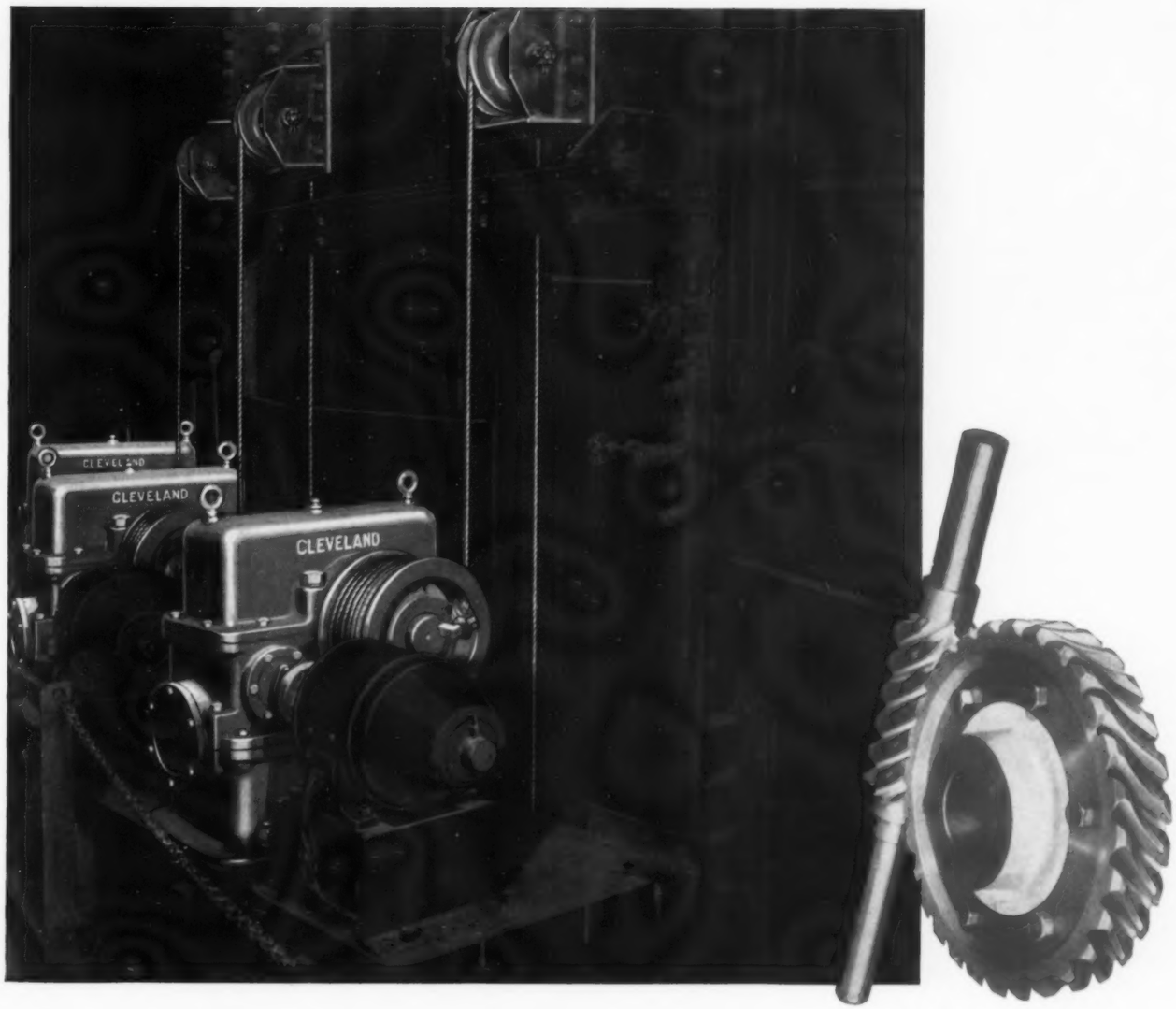
Built for Heavy Duty Service

Pyle-National plugs and receptacles provide safe and convenient handling of power supply for portable electrical equipment, and for control and instrument circuits. Controls for many types of operations can be concentrated, and provision made for the utmost flexibility in the handling of portable equipment. Pyle-National plug and receptacle equipment is built for heavy duty service, with full bakelite insulation, protected contacts and heavy drawn steel or cast metal housings. The complete line includes types for all services, in a range of capacities up to 200 amperes. Bulletins with complete listings will be sent upon request.

PYLE-NATIONAL

The Pyle-National Company, *General Offices and Works,* 1334-58 North Kostner Avenue, Chicago, Illinois • *Offices:* New York, Baltimore, Pittsburgh, St. Louis, St. Paul, San Francisco.

CONDUIT FITTINGS • LOCOMOTIVE ELECTRICAL EQUIPMENT • FLOODLIGHT PROJECTORS



Cleveland Winch Drives for Electrode Hoists

Six Cleveland Units on two 25-Ton electric furnaces serve as electrode hoists—with each Unit developing 48,000 inch pounds torque and having a total ratio of 630:1.

Only 4 moving parts are required to obtain this ratio in a compact, fully-enclosed Drive with no outboard bearing. Simplicity, rugged strength and the reliable performance of Cleveland Double Reduction Units qualify them especially for such exacting installations.

By producing four basic types in a complete range of sizes and ratios, we are able to supply standard units of the highest engineering and mechanical quality, and adapt them to practically every type of drive.

For 28 years, Cleveland has designed and built Worm Gearing exclusively, and a qualified District Representative will gladly call at your convenience.

The Cleveland Worm & Gear Company, 3278 East 80th Street, Cleveland, Ohio.

Affiliate: The Farval Corporation, Cleveland, Manufacturers of Centralized Systems of Lubrication
In Canada: PEACOCK BROTHERS LIMITED

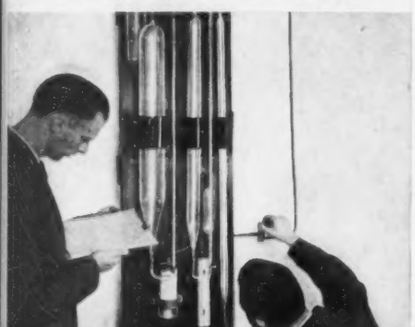
CLEVELAND
WORM GEAR *Speed Reducers*

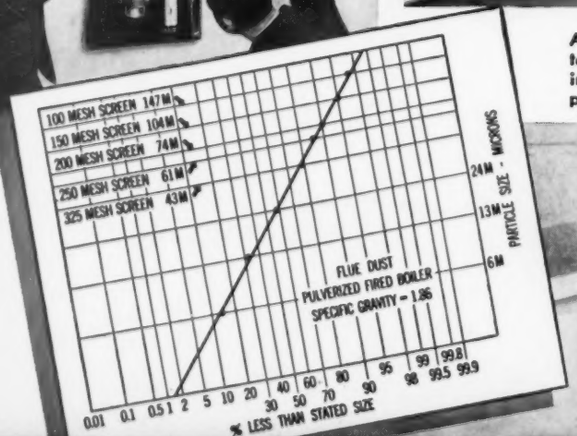
Research Tames

DUST ANALYSIS

Obtaining specimen of dust for analysis and for filing of permanent sample. Photomicrographs are made for visual analysis of size and nature of samples.

Vibrating screens grade dust particles into size groups. Below, unique Air Elutriator then separates dust, too fine for sieve grading, into 4 fractional sizes.




100 MESH SCREEN 147M
150 MESH SCREEN 104M
200 MESH SCREEN 74M
250 MESH SCREEN 61M
325 MESH SCREEN 43M
FLUE DUST
PULVERIZED FIRED BOILER
SPECIFIC GRAVITY - 1.86
24M
13M
6M
PARTICLE SIZE - MICRONS
0.01 0.1 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.8 99.9
% LESS THAN STATED SIZE

All dust fractions are carefully weighed to determine the percentage of each size in the sample. These percentages are plotted as shown in the graph, left.

EQUIPMENT DESIGN

The Detriscope, shown below, gives an actual picture of the passage and distribution of dust through a cyclone—and thus permits more efficient design.

Determining specific gravity of the dust. From the complete analysis, the performance of this dust in a cyclone can be accurately determined.

S-A
run.
and
whic

FLUE DUST

Special Sturtevant Laboratory concentrates on dust problems

The abrasive action of flue dust on induced draft fans, and the nuisance of fly ash, have long been problems of power plant engineers. Today, because of the increased use of pulverized fuel and greater boiler loads, these problems are even more acute.

While much progress in flue dust control has been made by Sturtevant since the development of the first Sturtevant fans over 80 years ago, today's increasingly serious flue dust problems demand special attention. To meet this need, the new, scientifically equipped Sturtevant Dust Laboratory, shown, has been established. It is concentrating a major part of its efforts on the flue dust problems of central stations and industrial plants.

Here, flue dust particles so small that they are invisible to the naked eye are considered of importance. They are painstakingly measured, graded, weighed, analyzed — because all this must be done before *adequate* collecting equipment can be designed.

Special equipment is utilized to classify the flue dust into even the finest micron sizes. New testing equipment was developed to determine the relative efficiency of separators. And finally, to insure installation performance in line with laboratory results, even new field testing equipment was developed.

The Sturtevant Dust Laboratory has enlarged the field of knowledge regarding flue dust control; improvements in collecting equipment have been achieved; and installations incorporating these improvements are already in successful operation.

B. F. STURTEVANT COMPANY, HYDE PARK, BOSTON, MASS.

Branch Offices in 40 Other Cities B. F. Sturtevant Co. of Canada, Limited — Galt, Toronto, Montreal

Sturtevant

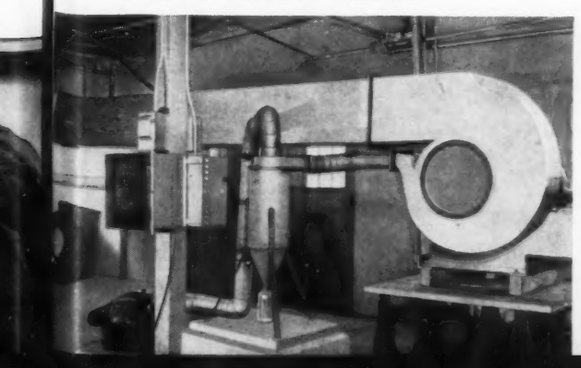
REG. U. S. PAT. OFF.

Puts Air to Work

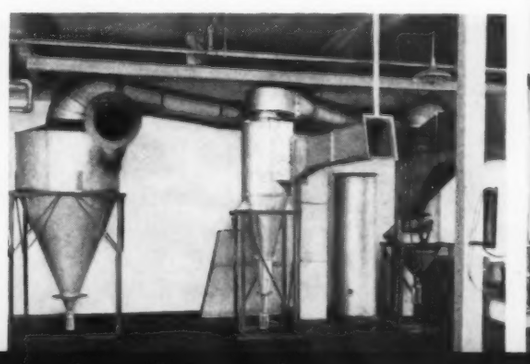
Because the performance of dust collectors is directly affected by the size and nature of dust particles, efficiency tests with various types of flue dust are made on all new cyclone designs.

On the test floor, above and below, are determined the answers to such questions as:—How does size of dust and size of collector affect efficiency? How does air velocity affect resistance and efficiency?

S-A Dust Collection Fan shown on a controlled test run. Fan at right separates and passes all the dust and approximately 10% of the air to the cyclone, which then completes the separation.



Tests on the Buell-VanTongeren Cyclone, center, and Sturtevant Cyclones, left and right, are used in combination with dust analysis in the solution of specific dust problems.



"3C" BULLETIN 100 TYPE "D" HEAVY DUTY PUSH BUTTONS OIL IMMERSED FOR CLASS 1, GROUP D, HAZARDOUS LOCATIONS

Closed View—Showing Sturdy Construction and Rounded Corners for Easy Operation and Avoidance of Skinned Knuckles

THE latest addition to the "3C" line of Type "D" Heavy Duty Push Buttons, an oil immersed station, features the same sturdy mechanism used in preceding Type D Buttons. These Push Buttons are built in accordance with Underwriters' specifications for Class 1, Group D, Hazardous Locations, with or without oil. The addition of oil eliminates the action of corrosive gas, and smothers any arc generated at the contacts.

The case consists of a heavy cast iron upper section, to which are attached the Push Button units, and a cast iron oil tank, both with wide, accurately machined flanges, thus completely assuring the cooling of any flame which may be started by explosion in the enclosure.

Provision is also made for locking in the "OFF" or "STOP" position.

Each Push Button unit has a Normally Open and a Normally Closed Contact supplied as standard. Maintained Contact Push Buttons are also available.

The Push Button units are mounted on an easily removable insulating subbase, which also acts as a wire spacer.

Our nearest office or agency will gladly give you further details.

Open View—Note Wide, Accurately Machined Flanges and Full Capacity Oil Tank

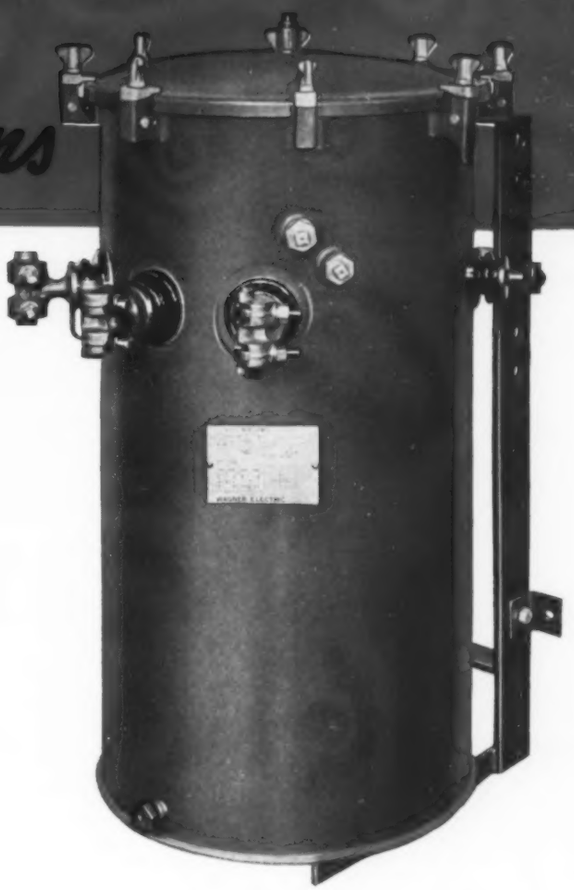
CONTINUE TO ROLL WITH CLARK CONTROL

THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO

WAGNER NOFLAMOL NON-INFLAMMABLE LIQUID FILLED TRANSFORMERS

save money on transformer installations



NOFLAMOL is a non-inflammable, synthetic liquid developed as an improvement over regular transformer oil. It has all the desirable properties of the highest quality transformer oil plus the advantage of being safe to use in transformers that are installed in locations where regular oil-filled transformers would constitute a fire hazard.

Because of the non-inflammable characteristics of Noflamol, Wagner Noflamol transformers have these money saving advantages:

1. Wagner Noflamol-filled transformers can be installed indoors without the use of expensive fireproof vaults, because Noflamol is non-inflammable. Considerable installation expense is thereby avoided.

2. Savings are effected by dividing the circuit into several sections and placing a Wagner Noflamol transformer at the load center of each, eliminating long runs of secondary copper, reducing line losses and improving voltage regulation.

3. The only foundation necessary for the installation of Wagner Noflamol transformers is a level floor strong enough to support the weight.

4. Wagner Noflamol transformers can be installed in out-of-the-way places or on beams up near the ceiling, thereby releasing valuable floor space for other uses.

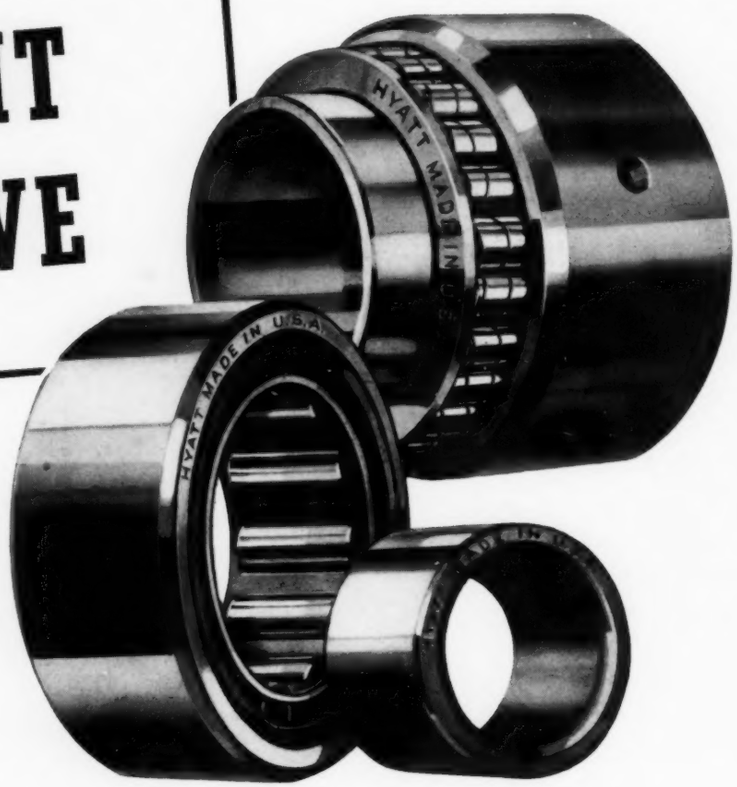
SPECIFY WAGNER NOFLAMOL NON-INFLAMMABLE LIQUID FILLED TRANSFORMERS

T40-13

Wagner Electric Corporation
6400 Plymouth Avenue, Saint Louis, Mo., U.S.A.

TRANSFORMERS • MOTORS • FANS • BRAKES

WHERE ONLY THE FIT SURVIVE



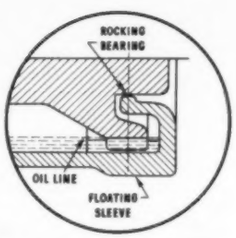
HYATT WOUND ROLLER TYPE AND HY-LOAD SOLID ROLLER BEARINGS shown opposite. Inherent design advantages, uniformity and accuracy, along with their capacity for heavy loads, account for the widespread application of these better bearings.

UNDER HEAVY LOADS day in and day out . . . Hyatts run smoothly and enduringly! No matter what the application—Hyatts keep equipment working . . . survive where others fail! Everywhere Hyatt Roller Bearings are proving their mettle and are assuring dependable operation and longer equipment life! Let us give you further facts about these better bearings for the machines you build or buy! Hyatt Bearings Division, General Motors Sales Corporation, Harrison, New Jersey; Detroit, Chicago, Pittsburgh and San Francisco.

HYATT *Roller* BEARINGS

FAST'S COUPLINGS

Self aligning



This sectional view shows Fast's construction. The load-carrying surfaces are protected against wear by a positive film of oil. This oil is kept permanently clean by the rocking bearings which make precise metal-to-metal contact and are in the one position where they form permanent dust and moisture proof seals. These vital features are found only in "Fast's."

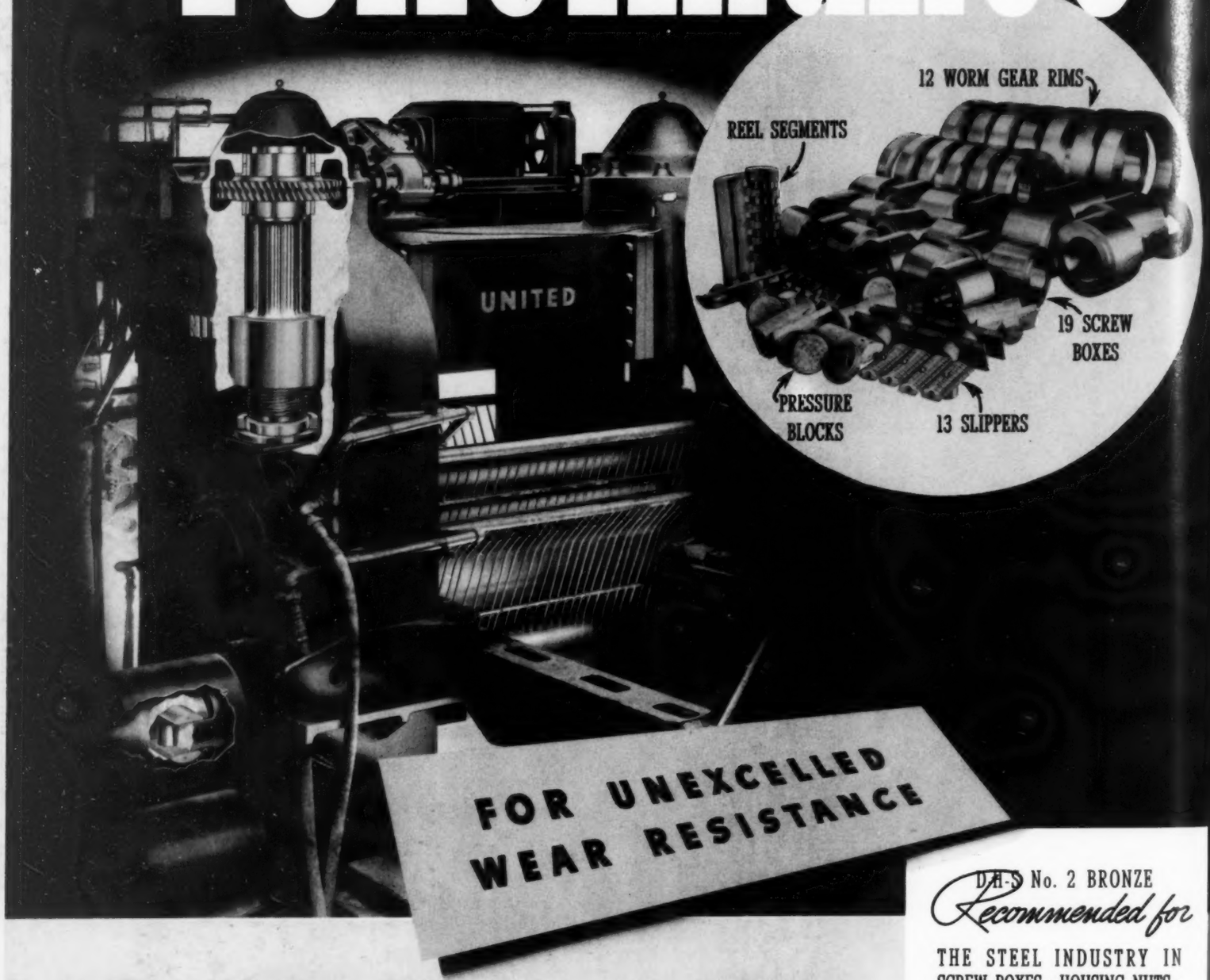
The busier you are, the more a shut-down costs—and the more reason there is to insist on completely dependable couplings. To be sure of the trouble-free, proven performance for which "Fast's" are noted, specify *genuine* Fast's Couplings on the machinery you purchase. Write for catalog.

KOPPERS COMPANY · BARTLETT HAYWARD DIVISION · BALTIMORE, MARYLAND

● **OTHER KOPPERS PRODUCTS FOR THE STEEL FIELD:** Coal . . . Coke . . . Coal Handling and Preparation Plants and Equipment . . . Coke Oven Plants . . . Gas Holders and Equipment . . . Purification Systems . . . Materials Handling Systems . . . Treated Timber . . . Waterproofing . . . Lumino and Bituminous Base Paints . . . Built-up Roofs . . . D-H-S Bronze . . . American Hammered Piston Rings and Packing . . . Hot Metal Transfer Cars . . . Ships, Barges and Dry-Docking Facilities.

a KOPPERS product

PROVED Performance



FOR UNEXCELLED WEAR RESISTANCE

DHS BRONZE

DUCTILITY · HARDNESS · STRENGTH

LONGER LIFE • LOWER COST

CASTINGS AND FORGINGS

KOPPERS COMPANY • BARTLETT HAYWARD DIVISION • BALTIMORE, MD.

OTHER KOPPERS PRODUCTS: Coal • Coke • Coal Handling and Preparation Plants and Equipment • Coke Oven Plants • Gas Holders and Equipment • Purification Systems • Materials Handling Systems • Treated Timber • Waterproofing • Lumino and Bituminous Base Paints • Built-up Roofs • American Hammered Piston Rings and Packing • Hot Metal Transfer Cars • Ships, Barges and Dry-Docking Facilities • Fast's Self-aligning Couplings.

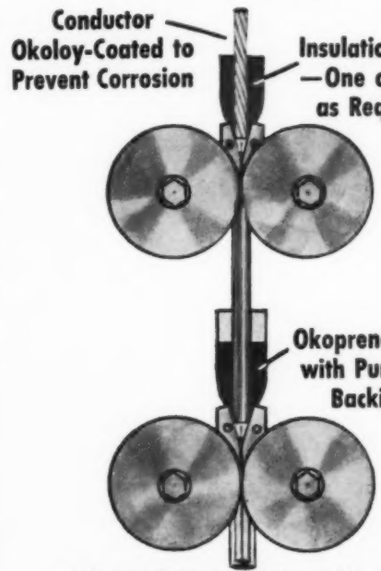
D.H.S No. 2 BRONZE *Recommended for*

THE STEEL INDUSTRY IN SCREW BOXES • HOUSING NUTS • WORM GEAR RIMS • WINDING REEL SEGMENTS • SLIPPERS • PRESSURE BLOCKS • SLAB PUSHER NUTS • MIXERNUTS • LEAD SCREW NUTS • TRUNNION BEARINGS • KEYS • SHEARGUIDES • BUSHINGS • LATCHBOXES • PIVOT BLOCKS • ROLL END BEARINGS

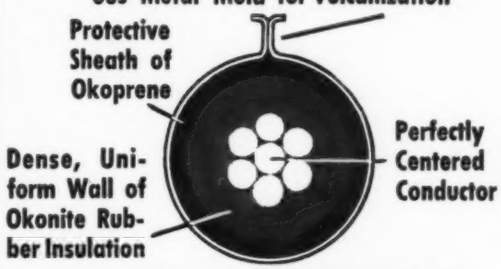
a KOPPERS *product*

A SIMPLE SOLUTION FOR ELECTRIC CABLE PROBLEMS

Perishable Braids and Lead Sheaths Eliminated by New Cable Design


Conductor Okoloy-Coated to Prevent Corrosion
Insulation Strip —One or More as Required
Okoprene Strip with Pure Tin Backing

Enlarged Cross-Section Showing Tin Forming Temporary Continuous Metal Mold for Vulcanization



The tin mold remains on the wire during vulcanization. It is then removed and the insulated wire with its bonded Okoprene jacket is ready for installation.

Neoprene-protected Cables Meet Steel Mill Needs

Many advantages follow the installation of Okoprene-sheathed electric cables in steel mills.

FIRST, the Okoprene sheath (60% neoprene) is non-inflammable.

SECOND, it is non-metallic and therefore, corrosion-resistant.

THIRD, there are no braids to rot.

FOURTH, Okoprene withstands oil.

FIFTH, Okoprene is highly resistant to sunlight, air and ozone.

Okoprene sheaths are bonded to the rubber insulation of Okonite wires and cables during the manufacturing process described in the adjacent panel. Thus applied, Okoprene provides a covering that permanently protects the electrical insulation.

Okoprene-sheathed cables are available in the full range of capacities and sizes needed for all steel mill use including power feeders, duct lines, general wiring and portable cords and cables. Write for information.

OKONITE-OKOPRENE

THE OKONITE COMPANY
Passaic, New Jersey
Offices in principal cities

OKOPRENE— OKONITE
Sheathed Wires and Cables

THE MACKINTOSH-ABRAMSEN

Straightener

Here is how it works

The Mackintosh-Abramsen Straightener consists of three pairs of horizontal cross rolls, which are arranged in the form of symmetrical passes. The six rolls, forming the three passes, have identical contours, and clamp the stock on its surface along a straight line parallel to its center line. The power is applied to the entering and leaving pairs of rolls by means of duplex drives and spindles. The middle pair of rolls is set out of line with respect to the entering and leaving pairs, thus creating a double bending effect on the stock as it rotates through the machine. Production speeds up to 500 feet per minute have been attained. Independent angular adjustment of each roll by handwheels makes it possible to obtain ideal settings for each kind and size of stock being run.

MACKINTOSH-HEMPHILL COMPANY ALSO PRODUCES THE STEEL INDUSTRY'S GREATEST ROLLS

"Techni"

PROCESS ROLLS

"Techni" Process Rolls will eliminate your roll troubles. They will help you cut costs and increase your production. Let us tell you the details about Mackintosh Rolls made by the "Techni" Process. Write for information or for one of our engineers today.

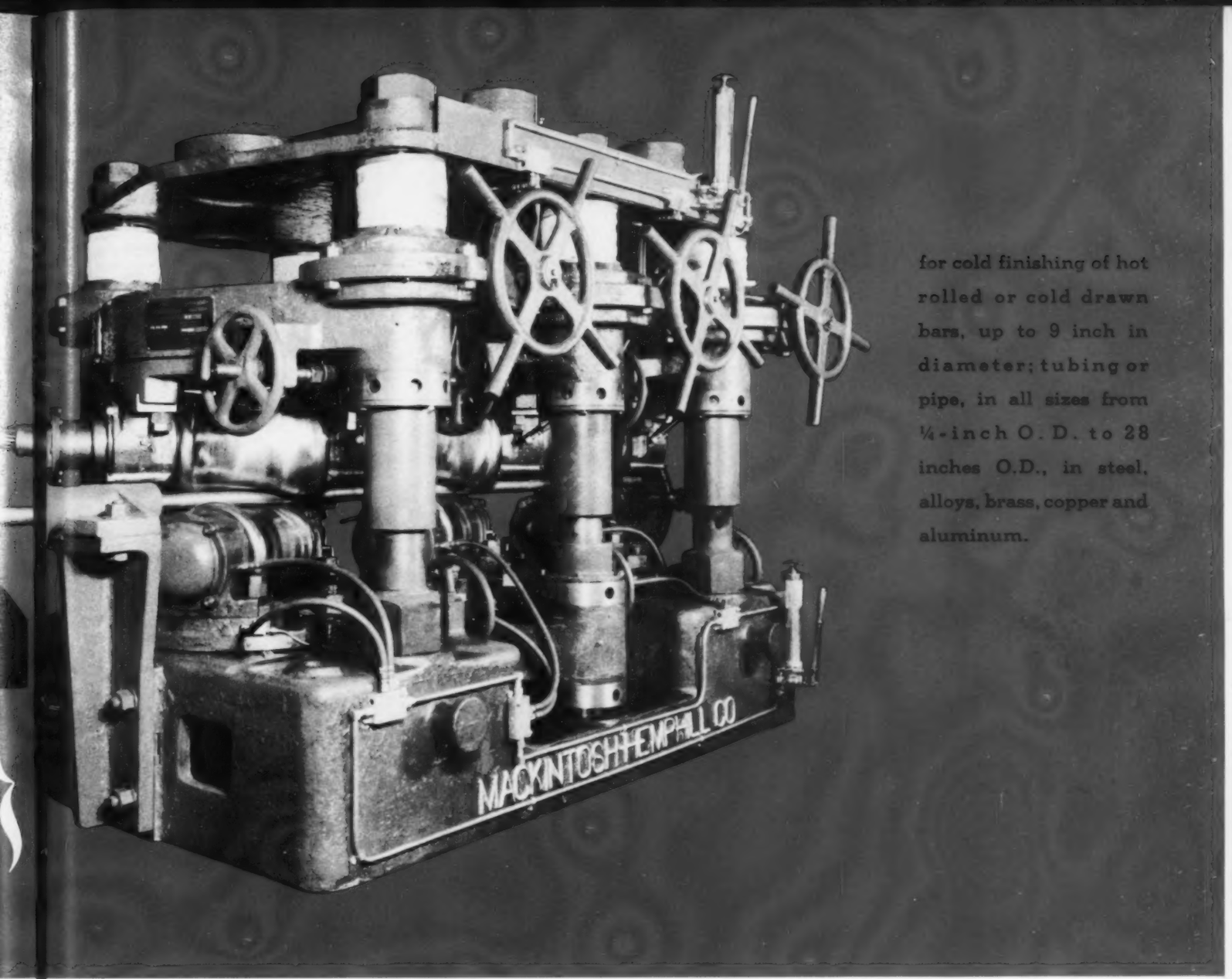
Here's what it does

Based on an entirely new and thoroughly proved principle, designed and built by an organization known and recognized for quality since 1803, the Mackintosh-Abramsen Straightener speeds up production, cuts operating costs and delivers an absolutely straight product—end to end—that meets the most exacting demands for straightness and size.

There are no guides to ring or score the stock. The action of the rolls can be controlled to produce the exact quality of surface finish that is required.

Elimination of supporting guides, the use of symmetrical passes and a balanced arrangement of the drives, results in a very considerable savings in power—the power consumed per foot of product sized or straightened is usually about fifty percent of that required by other types of machines.

MACKINTOSH-



for cold finishing of hot rolled or cold drawn bars, up to 9 inch in diameter; tubing or pipe, in all sizes from ¼-inch O. D. to 28 inches O.D., in steel, alloys, brass, copper and aluminum.

The absolute straightness of stock produced by the Mackintosh-Abramsen Straightener is accomplished by having the middle pair of rolls out of line with respect to the other two pairs, thus giving the ideal condition for end to end straightening. The double roll middle pass prevents weaving or sidewise movement of the stock in this pass and causes straightening of long bends and end camber to take place in three passes instead of one, hence the bending action on the stock takes place from the end of the rolls in the first pass to the end of the rolls in the middle pass, and again from the middle pass to the third pass. Thus the bending or straightening action on the stock is from section to section of the stock, and is not dependent on the contour of the rolls forming the pass.

The symmetrical contour of the rolls forming the three passes and the balanced arrangement of the driven rolls result in a uniform wear on the surface of the roll. The rolls are continuously "wearing in" instead of "wearing out." The machine, therefore, requires fewer roll dressings and, hence, gives greater roll life.

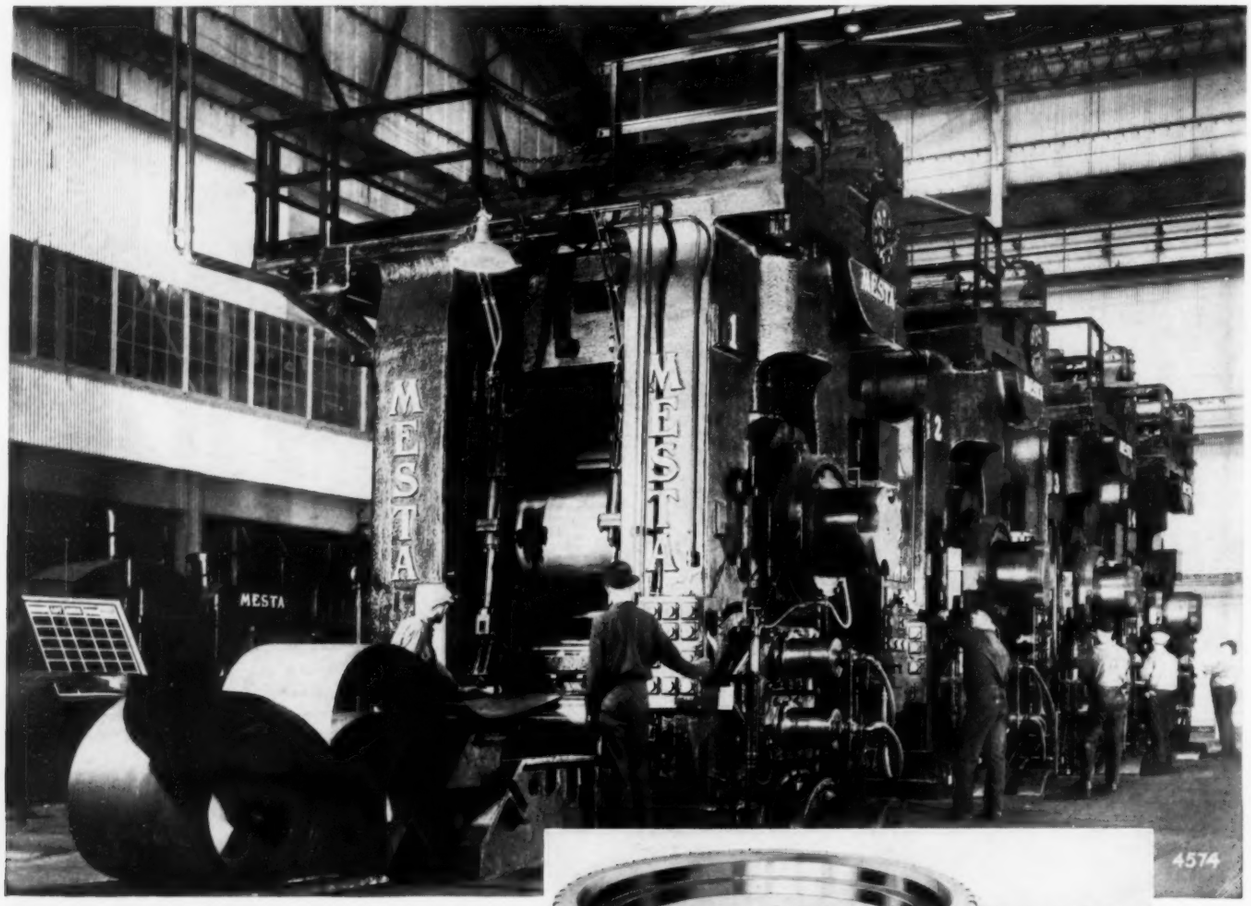
Because there is nothing "closed in" about these machines, you can reach all parts, make adjustments and roll changes easily, rapidly. This means less "down-time" and increased production—the straightener stays on production longer, turns out more feet of product.

Take advantage of this precision machine—turn out straighter, more uniform products—products that will more than meet your customers' exacting standards.

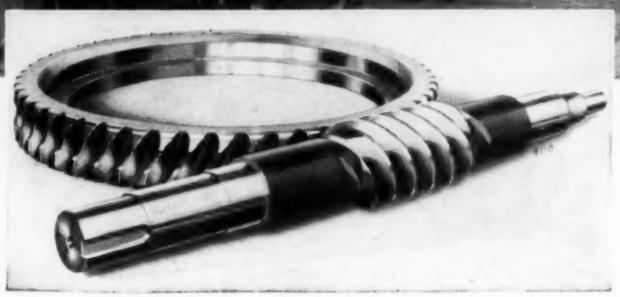
Telephone, wire or write for a Mackintosh engineer. He'll be glad to show you how other manufacturers are producing superior products—straighter products—at lower costs.

HEMPHILL COMPANY, Pittsburgh and Midland, Pa.

Other Mackintosh-Hemphill Company products: "Techni" Process Rolls . . . Rolling Machinery . . . Shape Straighteners . . . Strip Coilers . . . Shears . . . Levellers . . . Pinions . . . Special Equipment . . . Iron-Steel Castings.



Feeding strip steel from coils into 54 in., four high, four stand, tandem cold rolling mill; screwdowns operated by De Laval Worm Gear Sets.



Developing a

NEW MACHINE?

Experienced designing engineers save time and expense by utilizing, wherever suitable, well proven elements, so that attention and effort may be concentrated on the NEW PROBLEMS involved.

DE LAVAL WORM and WORM WHEEL SETS

meet varied speed transformation requirements and, because of compactness, right-angle drive, self-lubrication, and great range of ratios, often permit of marked simplification and improvement of machines in which they are incorporated. The designer receives not only the benefit of specialized manufacturing equipment and methods developed through our many years in the manufacture of high grade speed reducers, but he can also draw upon our extensive experience with a great variety of speed reducer applications.

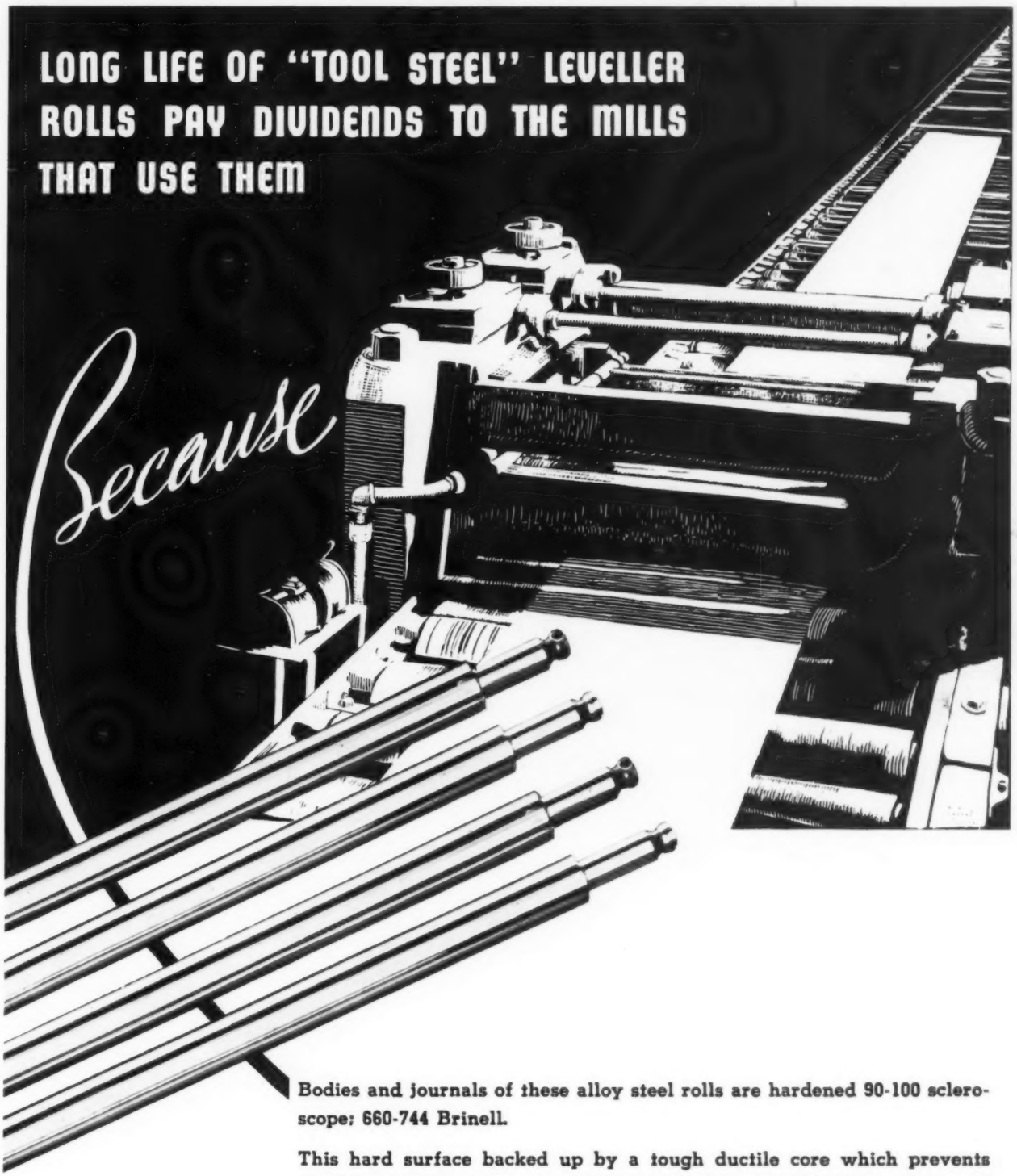
The De Laval engineers will gladly submit data and recommendations upon learning of proposed plans and requirements.

Ask for Catalog W 1121

DE LAVAL WORM GEAR DIVISION
of the De Laval Steam Turbine Co., Trenton, N. J.

LONG LIFE OF "TOOL STEEL" LEVELLER ROLLS PAY DIVIDENDS TO THE MILLS THAT USE THEM

Because



Bodies and journals of these alloy steel rolls are hardened 90-100 scleroscope; 660-744 Brinell.

This hard surface backed up by a tough ductile core which prevents breakage of the rolls at the necks, gives them an added life which will save your company money in roll cost, maintenance, and the improvement of the product rolled.

THE TOOL STEEL GEAR & PINION CO.

CINCINNATI, OHIO

BUT MOTORS STAY AND WORK

Yes, motors stay and work as long as the insulation on their windings can resist the heat built up by continuous operation and peak loads. The proper magnet wire is a serious problem right now because motors in many plants are working at peak capacity—especially in the steel industry.

Peak loads build up intense motor heat. Continuous operation allows no cooling-off periods. These conditions are very hard on motors wound with ordinary magnet wire. The insulation on that wire breaks down rapidly, and the motors stop. That means trouble and expense.

Deltabeston, Deltaglass, Formex Asbestos, and Formex Glass Magnet Wire can withstand the heat built up by peak loads and continuous operation. Deltabeston Magnet Wire performance is assured by the extreme purity of the asbestos used and the efficiency of the patented "felting" process which applies that asbestos to the copper conductor.

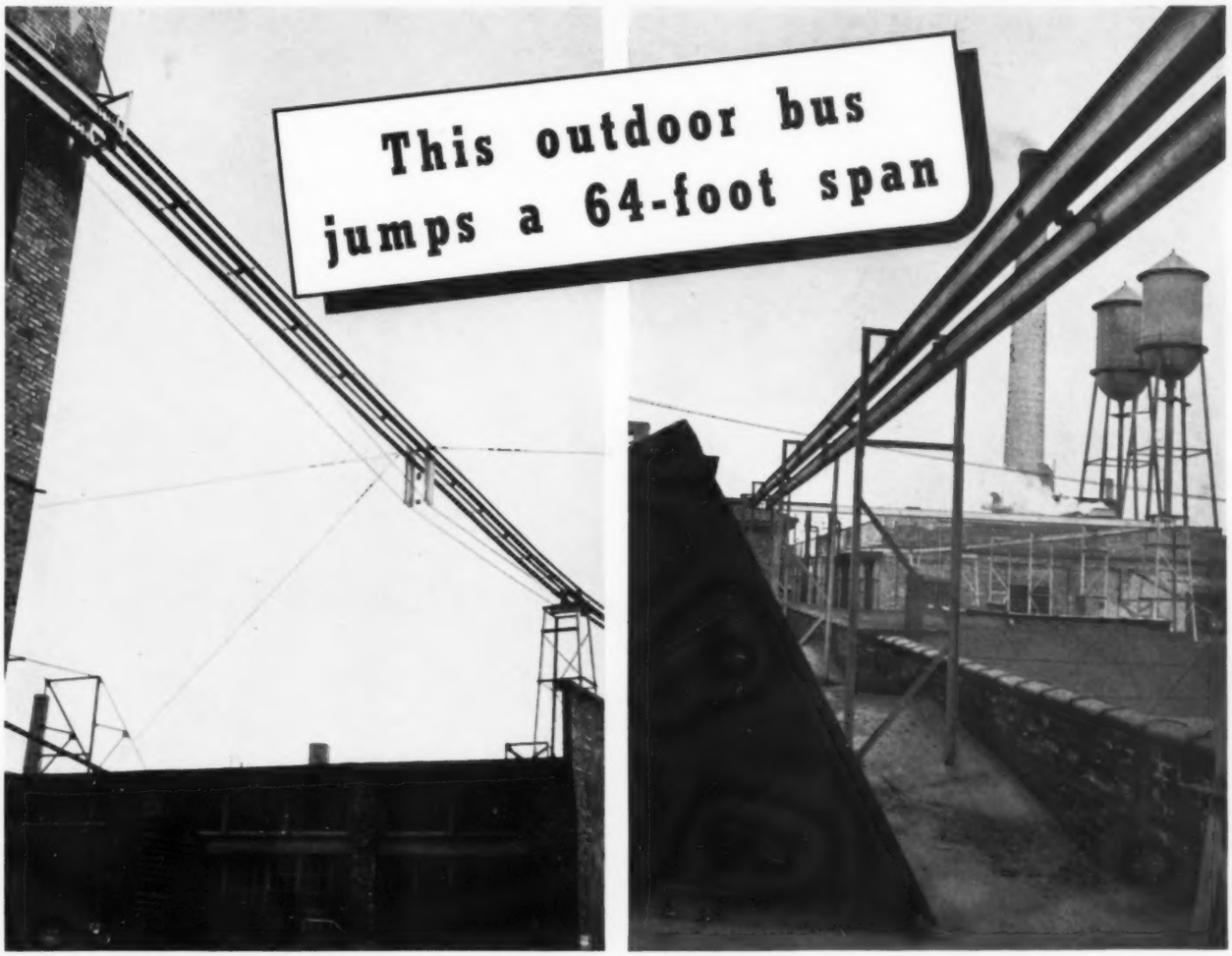
Deltaglass magnet wire possesses the inherent heat-resisting properties of spun glass. In addition, it is protected by special varnishes which greatly increase its dielectric strength.

Formex asbestos and Formex glass are high-quality G-E Magnet Wires with outstanding heat resistance.

To cut down your motor repair bills, specify Deltabeston or Deltaglass magnet wire on your new motors. If your present motors must be sent out for rewinding, specify that Deltabeston or Deltaglass be used on them. Then when they come back to you they'll be ready to work for a long time in spite of the heat from peak loads and continuous operation.

If you do your own motor repair work you can purchase these General Electric magnet wires from all G-E Merchandise Distributors and from the Graybar Electric Company.

GENERAL ELECTRIC



Two 8-inch Alcoa Aluminum channels, bolted back to back, form each leg of this bus installation. The natural stiffness of the channels permitted the use of long spans. Where the bus jumps sixty-four feet across a street and a railroad track, simple truss construction was used.

The bus runs 430 feet, indoors and out. Aluminum was chosen because it offered the best combination of mechanical and electrical characteristics. It has high current-carrying capacity.

Light in weight, Aluminum buses—tubular, flats, channels or angles—place less burden on supports. Structures can be lighter, with the result that you save money all around. Standard construction methods and simple, inexpensive fittings are used with Alcoa Aluminum buses.

ALUMINUM COMPANY OF AMERICA, 2128 Gulf Building, Pittsburgh, Pennsylvania.

Why should I specify Neloy???

NE

First, because Neloy and Neloy Molybdenum steel castings possess higher physical properties at *very little* more than carbon steel base price. Secondly, they are produced under one *complete control*, from raw material to finished product . . . machined or unmachined at the National-Erie Corporation.

Qualities of* Neloy *for Flame Hardening.

1. **No sharp line of demarcation between the case and the core nor quick change in chemical analysis as with case hardened material.**
2. **The surface material depends not on hardness alone, but combines high hardness and toughness to resist wear and impact.**
3. **A core value that is equal to that of alloy steel, offering fatigue or impact values much higher than the regular case hardened product.**
4. **Hardened depth for necessary wear resistance equal to case hardening treatment at about one-third the cost.**
5. **A surface that will not spall with vibration or impact.**

Better get their Bulletin #5— Miss Jones

Neloy Steel
Gear Tooth annealed.

Neloy Treatments
No. 1 to 9 inclusive, note texture of cross-section

Flame hardening
Neloy 10-A and B . . .
Note depth of hardness.

NATIONAL-ERIE
CORPORATION
ERIE, PA., U.S.A.

New INGOT CARS

and an IMPROVED BEARING MOUNTING

SKF

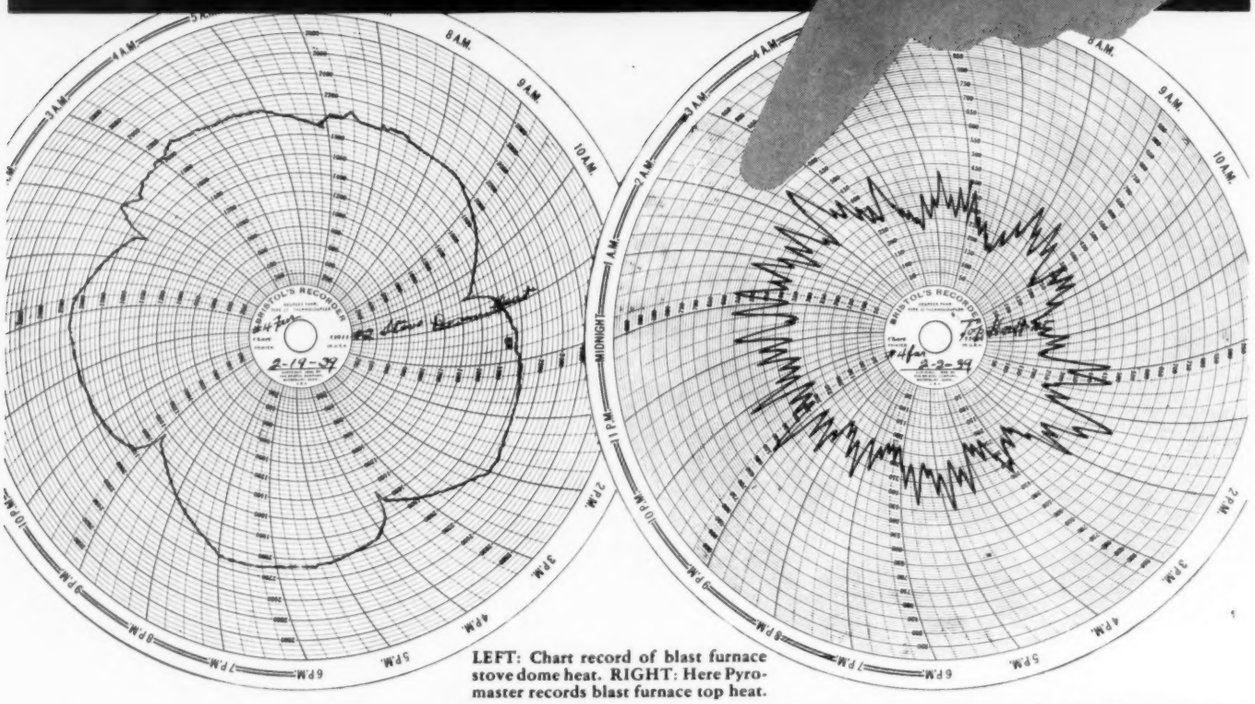
ROLLER BEARINGS

Cooperation between SKF, an ingot car builder, and the steel company brought about the adoption of a simple, highly effective and improved bearing mounting—a mounting that is justifying in service the expectations of its designers. Such cooperation leads to progress and success. YOUR *equipment* is only as good as its bearing mountings; OUR *co-operation* is always available. 4663

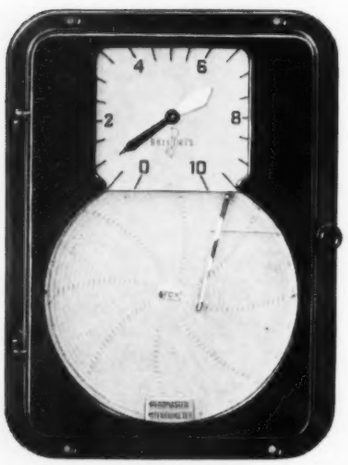
SKF INDUSTRIES, INC., PHILADELPHIA, PENNA.

YOUR FURNACE'S DAILY "LIFE"

at your Finger-tips!



LEFT: Chart record of blast furnace stove dome heat. RIGHT: Here Pyromaster records blast furnace top heat.



WHAT is the true temperature in your furnace, oven or other heating process? Is it fluctuating widely, rapidly, or only slightly, gradually? What was it this morning, last night?

Bristol's Pyromaster Potentiometer Pyrometer not only puts this important information at your finger-tips in the form of a large, easy-to-read, round chart record—ideal for filing, future reference and guidance—but also offers you these definite features that make Pyromaster the *best Pyrometer your money can buy:*—

1. Strong and rugged,—ideal for severe steel plant service.
2. Unaffected by vibration. Shock-proof!
3. Instant response.
4. No motion of any working part *except* when temperature is changing. No need for stocking replacement parts!
5. Free from need for lubrication. No standard cell.
6. Jewelled pivot galvanometer. Operates in any position!
7. Easy to inspect or service.
8. Compact for convenient mounting. Lightweight.
9. Round chart an added convenience. Indicating dial if you want it.
10. Surprisingly economical in first cost and operating cost.
11. Supplied also (a) for either air or electric control; (b) in model furnishing two continuous records on the same chart; (c) with an explosion-proof case for hazardous installations.

Write for Bulletin 507Z and Catalog 1452Z

THE BRISTOL COMPANY, WATERBURY, CONNECTICUT

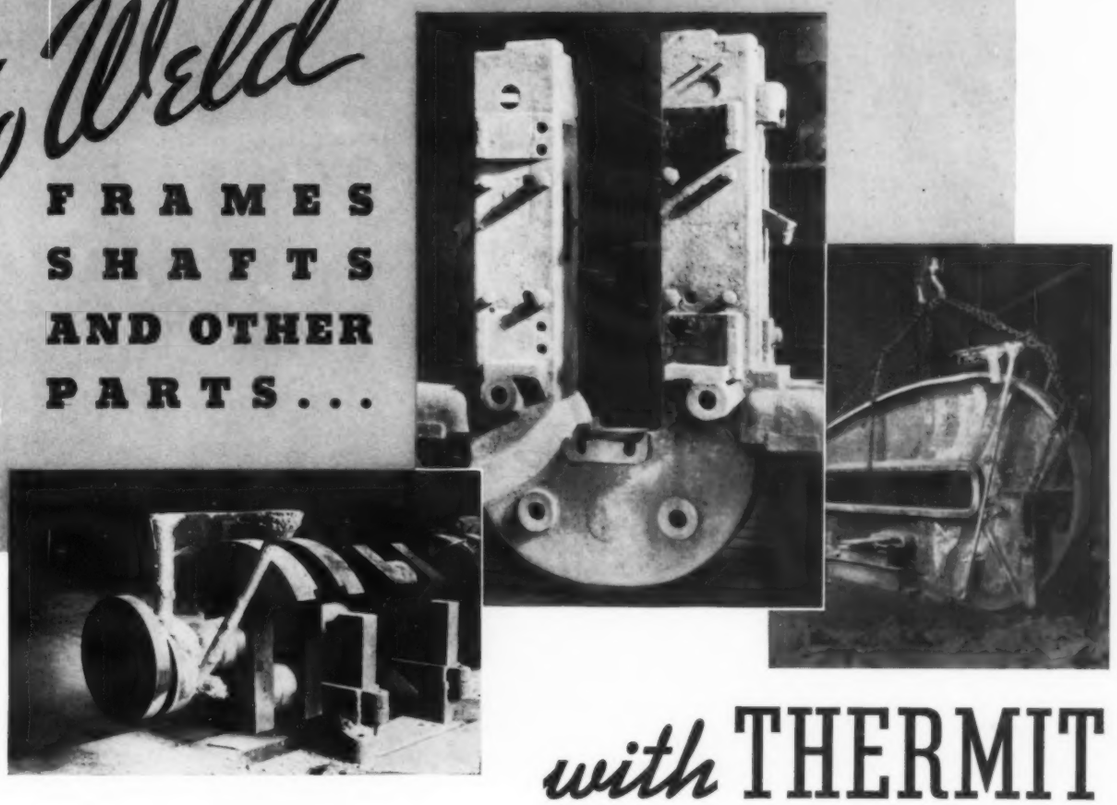
BRISTOL'S PYROMASTER

POTENTIOMETER PYROMETER

IT WILL PAY YOU

to Weld

FRAMES
SHAFTS
AND OTHER
PARTS...



with THERMIT

Broken rolls, pinions, housings, crankshafts and other parts are salvaged from the scrap pile and repaired the Thermit way at a fraction of replacement cost. Further economies are effected by avoiding the long delays and costly shut-downs that result when new parts must be cast or forged. Actual savings on individual emergency repairs frequently amount to thousands of dollars.

Our engineers, backed by many years of practical experience in steel mill work, will be glad to show you how such savings can be made. Let them check over your scrapped equipment and report on parts that can be repaired at a profit to you.

Write today and ask to have a representative call. Or, as a starter, send for a copy of the booklet: "Thermit Welding".

THERMIT WELDING

"For better results in electric arc welding, investigate MUREX-HEAVY COATED ELECTRODES"

METAL & THERMIT CORPORATION • 120 BROADWAY, NEW YORK
ALBANY • CHICAGO • PITTSBURGH • SO. SAN FRANCISCO • TORONTO

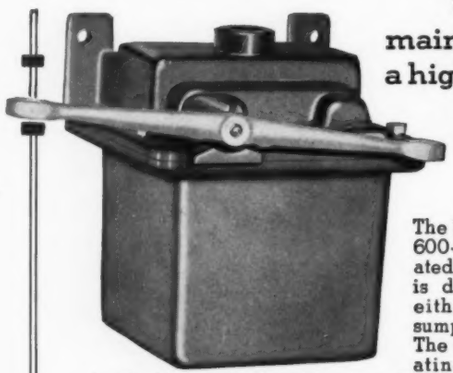
If it's
OIL IMMERSED
PUSH BUTTONS—

ROWAN HAS THE MOST COMPLETE LINE AVAILABLE

Bulletins 3961 and 3962 show the many circuit arrangements available in the standard and Class 1, Group D, push button stations. The data contained in these bulletins simplifies the selection of push buttons for various applications. Copies on request.

ROWAN CONTROL
THE ROWAN CONTROLLER CO., BALTIMORE, MD

OIL-IMMERSED FLOAT SWITCH
for maintaining a high or low liquid level



The Rowan Type 600-1 rod operated Float Switch is designed for either tank or sump operation. The entire operating mechanism is oil immersed, making it particularly suited for use in corrosive atmospheres. It is of the quick acting make and break type and is not affected by oscillating liquids.

The Type 600-1 switch has a liberal rating and can be used either as a pilot switch or for direct operation of fractional horsepower motors.

Bulletin 3911 on request.

Type 600-1 switch designed to conform with the manufacturer's interpretation of the Underwriters' Laboratories, Inc. standards but not listed or tested by Underwriters' Laboratories, Inc.

THE ROWAN CONTROLLER CO.
BALTIMORE MARYLAND

Thousands of Steel Mill Motors Lubricated with

NON-FLUID OIL—because it stays in bearings and off armatures. Oil-soaked windings are avoided, and burn-outs from short-circuits prevented.

Oil bills are also cut because NON-FLUID OIL outlasts 3 to 5 times. Production cost is lower, too; motors are kept in steady operation with no costly repairs.

Want proof? Send for testing sample today—prepaid—NO CHARGE.

•

New York & New Jersey Lubricant Co.

Main Office: 292 Madison Ave., New York, N. Y.

WAREHOUSES:

Chicago, Ill.	Atlanta, Ga.
St. Louis, Mo.	Detroit, Mich.
Providence, R. I.	Greenville, S. C.

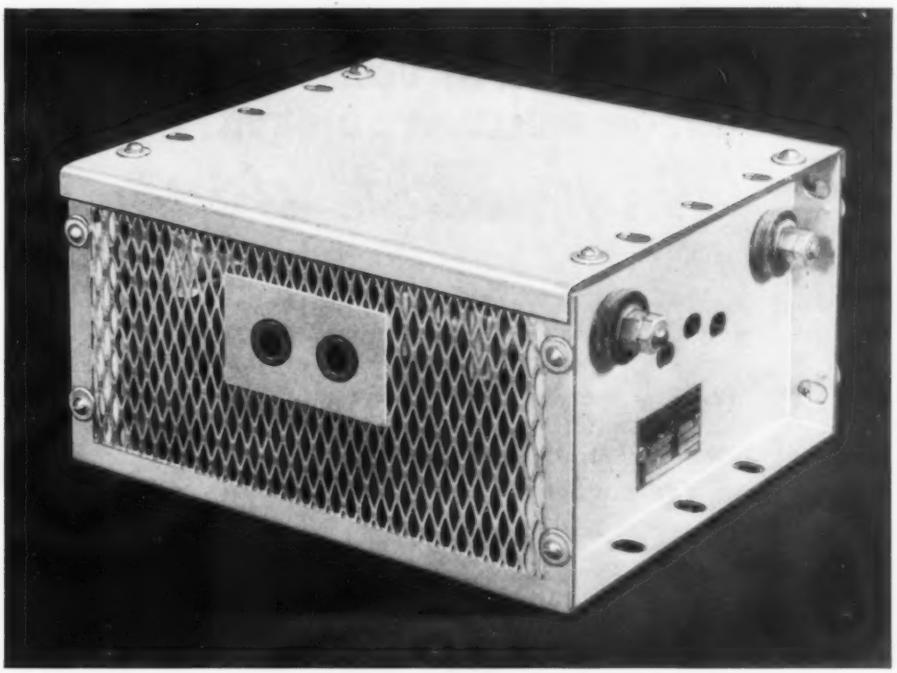
TRADE MARK REGISTERED
NON-FLUID OIL
IN U.S. PAT OFFICE & FOREIGN COUNTRIES

MODERN STEEL MILL LUBRICANT

Better Lubrication at Less Cost per Month

P-G *Limit Switch Resistors*

for use with . . . CRANE HOIST SAFETY LIMIT STOPS . . . !



P-G Limit Switch Resistors are manufactured in three standard groups—for any crane hoist safety limit stop operating on D-C. current—within a range of 5 to 200 HP.

Rugged construction with basic parts similar to P-G Standard Resistor Banks creates a unit unaffected by vibration, moisture or corrosive fumes. Compact enough to be easily mounted in any convenient spot, lengthy trouble-free service is assured.

Covered as illustrated, the resistor unit is amply protected from ordinary mechanical damage, yet adequate ventilation is provided.

P-G

For Safety use **P-G** *Unbreakable Resistors*

COMPLETE DATA IN NEW BULLETIN No. 500 . . . WRITE TODAY

THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

221 WEST THIRD STREET, CINCINNATI, OHIO

4

1500 KW - 250 VOLT-SYNCHRONOUS MOTOR GENERATOR SETS

for immediate shipment

These are Westinghouse units—compound wound, .8 P. F., 514 r.p.m. 3 phase, 60 cycle.

Unlike ordinary used equipment, these motor-generator sets are in first class electrical and mechanical condition. The cost of each is only a fraction of similar new equipment.

For complete details, write or wire to:

ELECTRIC GENERATOR & MOTOR CO.

4519 Hamilton Ave. Cleveland, Ohio

All About Arc Welding

THE NEW HANDBOOK

Your Guide to Progress

★ Here are the results of twenty years' fact-finding on the part of a staff of two hundred arc welding experts contacting every industry throughout the world. The new 6th edition "Procedure Handbook of Arc Welding Design and Practice" contains up-to-date facts about all aspects of arc welding and its many profitable applications, compiled and edited for quick reference and easy understanding. This authoritative reference guide will enable you to keep abreast of this fast-growing industry for personal advancement and profit. You cannot afford to be without this valuable new Handbook.

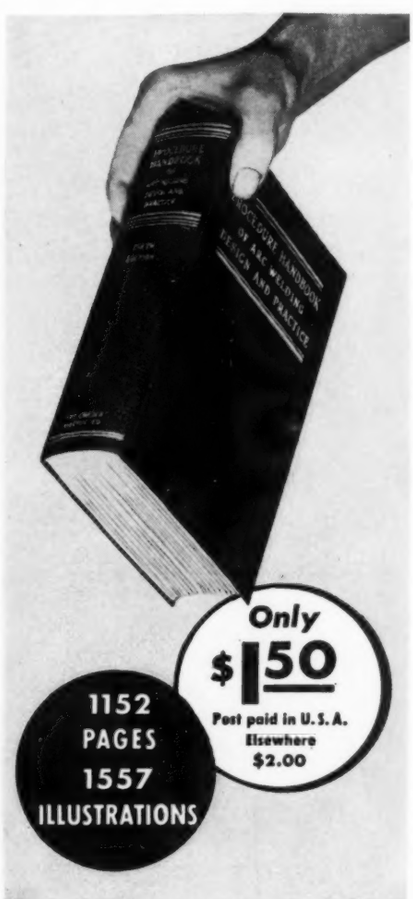
★ ★ ★

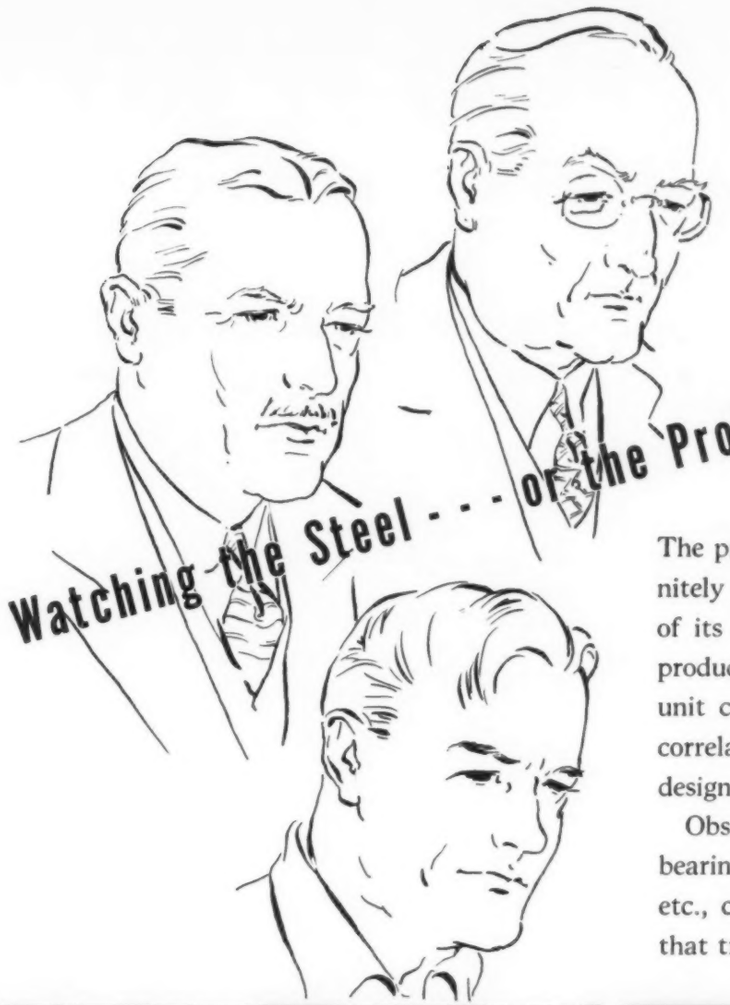
Complete in every detail. In eight parts—(1) Welding Methods and Equipment. (2) Technique of Welding. (3) Procedures, Speeds and Costs. (4) Weld Metal and Methods of Testing. (5) Weldability of Metals. (6) Machine Design. (7) Structural Design. (8) Actual Applications.

Recognized throughout the world as the authentic reference book on arc welding. More than 90,000 copies of first five editions have been sold. 6th edition is an entirely NEW Handbook, containing important new information. Written clearly. Well indexed for quick reference. Size 6" x 9" x 1⅝" —ideal for use in office, shop or school. Printed on fine paper. Bound in semi-flexible simulated leather—gold embossed.

Order your copy today. Mail your order and check to

IRON AND STEEL ENGINEER, 1010 EMPIRE BLDG. PITTSBURGH, PA.



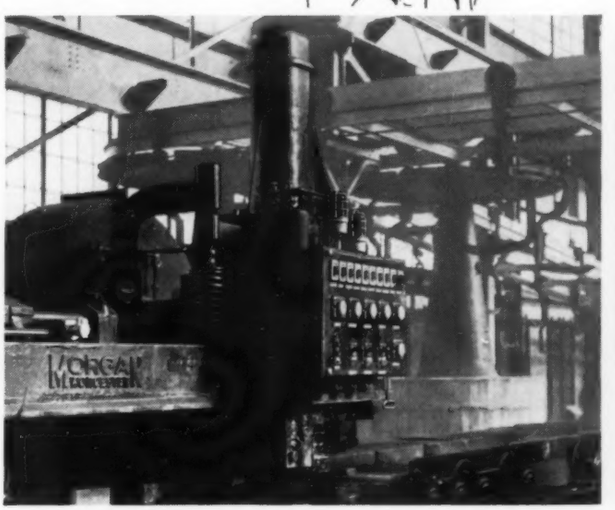


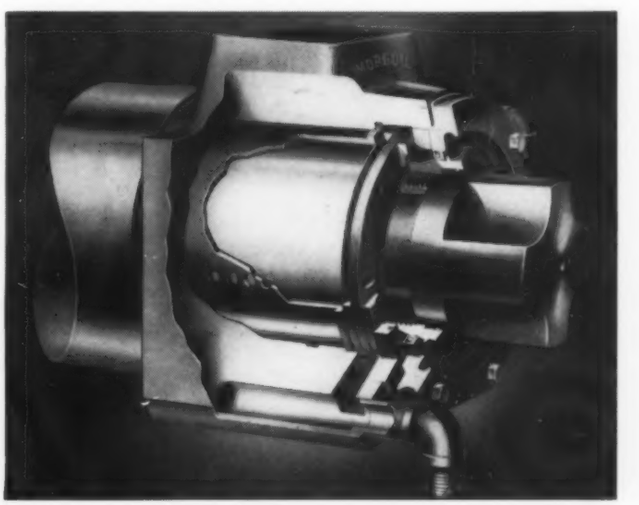
Watching the Steel - - - or the Profits go by — Which?

The productive capacity of *your* mill is definitely limited by the degree of coordination of its component parts. Increased range of product with increased tonnage and lower unit costs *will result only* from experienced correlation of all factors involved in the mill design and arrangement.

Obsolete types of equipment, roll neck bearings, tables, cooling beds, shears, coilers, etc., can all become expensive bottle necks that transform *profits* into *overhead.*

R-80

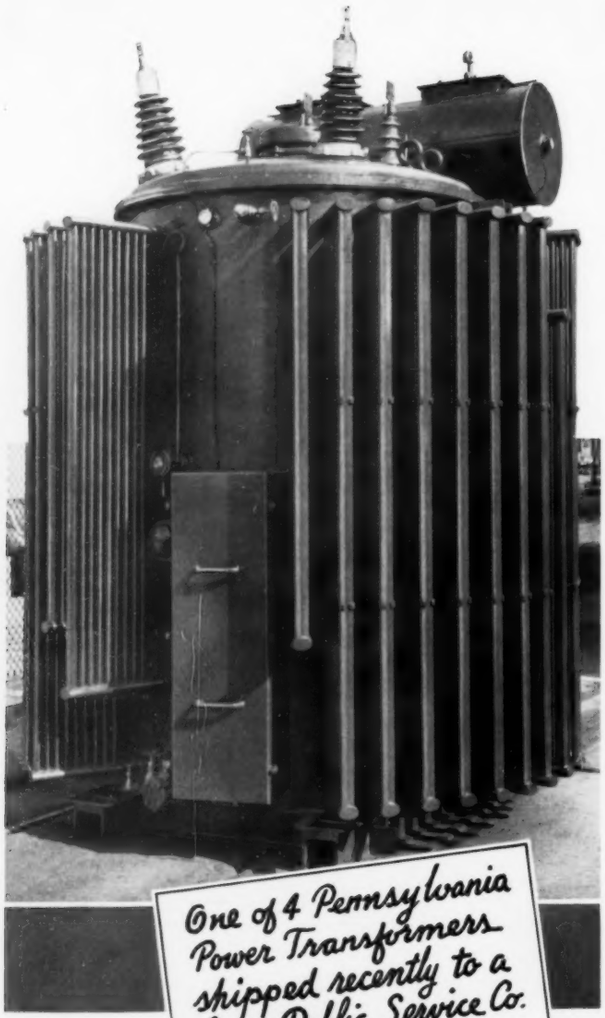




Left: Morgan Bar Shears are one of several types embodying improved design.
Right: Morgoil bearings ride on a film of oil. They offer extremely low coefficient of friction, high load capacity and freedom from wear. They are available in all capacities for replacement.

MORGAN
WORCESTER
ENGINEERS AND MANUFACTURERS

CONTINUOUS ROLLING MILLS
Rod • Strip • Skelp • Merchant Shapes
MORGAN CONSTRUCTION COMPANY, WORCESTER, MASSACHUSETTS



One of 4 Pennsylvania Power Transformers shipped recently to a large Public Service Co.

8333 kva, 36 kv, single phase. Equipped with standard Pennsylvania Uni-Flow Radiators and Straight-Line Tap Changers. Subjected to impulse, temperature run and other A. I. E. E. tests.

A DECADE OF PROGRESS IN BUILDING TRANSFORMERS 1929 1939

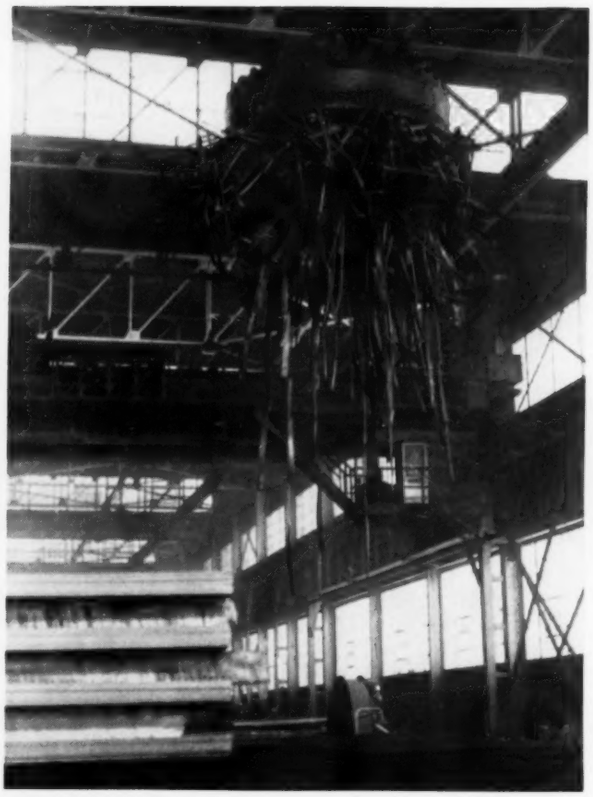
Pennsylvania

TRANSFORMER COMPANY

1701 ISLAND AVENUE, N. S., PITTSBURGH, PA.

OHIO

Maximum Lift MAGNETS



The cut shows a Super double strength 65″ Ohio Magnet lifting 3100 lb. of plate trimmings.

The same magnet lifts 5400 lb. of tangled plate scrap.

Best known lift on raw hot rolled strip steel was four 9000 lb. coils = 36000 lbs.

These lifts are more than double the average lifts of a standard 65″ magnet for such material.

OHIO Reliable MAGNETS

The OHIO Electric Mfg. Co.

5907 Maurice Avenue

Cleveland. Ohio

DROP HAMMERS

1,000 LBS. TO 16,000 LBS. CAPACITY

FORGING HAMMERS

150 LBS. TO 40,000 LBS. CAPACITY

FORGING PRESSES

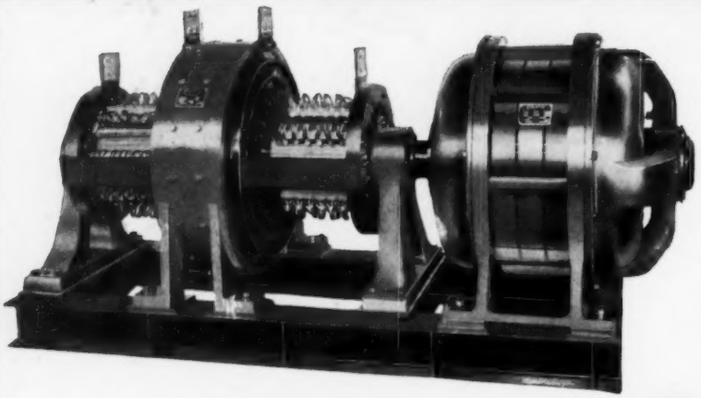
300 TONS TO 6,000 TONS CAPACITY

DESIGNERS • MANUFACTURERS
CONTRACTORS

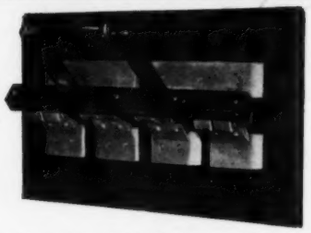
BLOOMING MILLS • PLATE MILLS
STRUCTURAL MILLS • ELECTRIC
TRAVELING CRANES • CHARGING
MACHINES • INGOT STRIPPING
MACHINES • SOAKING PIT CRANES
ELECTRIC WELDED FABRICATION
LADLE CRANES • STEAM HAM-
MERS • STEAM HYDRAULIC
FORGING PRESSES • SPECIAL
MACHINERY FOR STEEL MILLS

THE MORGAN *Engineering Co.*

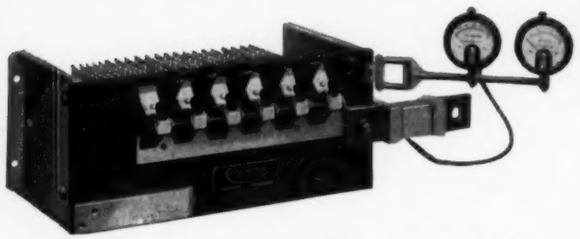
ALLIANCE, OHIO



Columbia Low Voltage Generators are built in sizes of ½ to 250 KW., 100 to 40,000 amperes, 6 to 60 volts.



Columbia Reversing Switches are of the double pole, double throw type, for use as a reversing switch or series parallel switch on circuits up to 15 volts, 200 to 2,000 amperes.



Rheostat sizes range from 15 to 5,000 amperes and with a 3 to 6 volt drop.

Designed and Built to Meet the Exacting Needs of the Modern Plating Department and for 24-hour Daily Operation.

COLUMBIA ELECTRIC MFG. CO., 4512 Hamilton Ave., Cleveland, Ohio

LOW VOLTAGE GENERATORS — COLUMBIA — PLATING TANK RHEOSTATS

REVERSING SWITCHES

$ Savings + Protection!

TRICO REG. U.S. PAT. OFF.

UNBREAKABLE OILERS

OPTO-MATIC — GRAVITY FEED — WICK FEED

- SMART STREAM-LINED DESIGN
- CRYSTAL-CLEAR PLASTIC BOTTLES
- OUTSTANDING IN PERFORMANCE

TRICO visible automatic lubrication is the ultra-modern way to stop waste and failures caused by old-fashioned trust-to-luck hand oiling methods.

WRITE FOR BULLETINS

This Famous TRICO COMBINATION

is saving users thousands of dollars annually thru the elimination of unnecessary shutdowns caused by fuses unmistakably poor in design—and bad clips. Safe, efficient and dependable protection automatically predominates.

TRICO Powder-Packed FUSES

The renewal element is different. It's *powder-packed* and custom-built for accuracy, dependability and utmost efficiency. It's loaded with engineering refinements that guarantee safe and dependable performance beyond comparison and gives you THREE TIMES THE SERVICE—all at NO EXTRA COST.

KLIPLOK CLAMPS

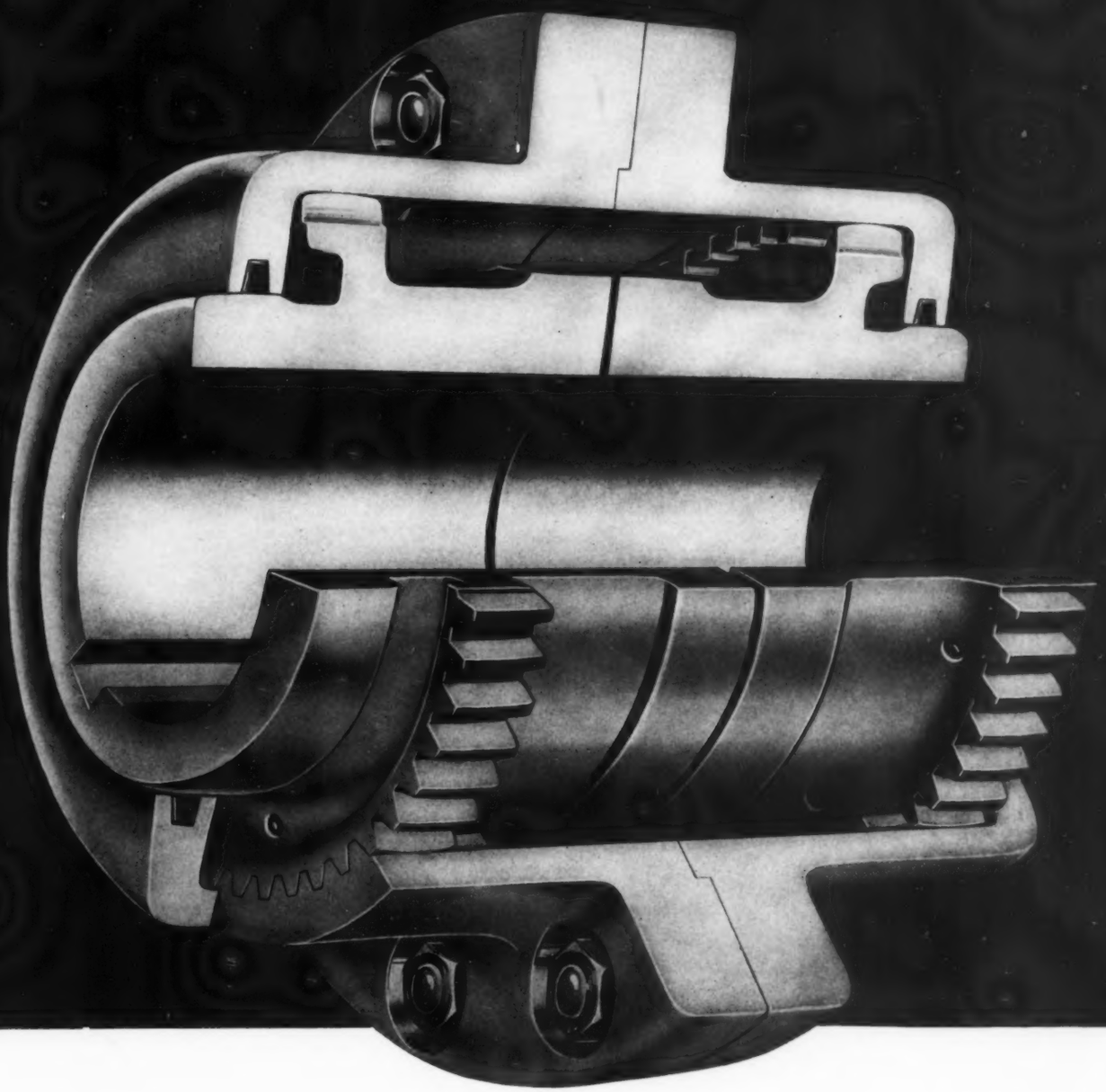
Lock fuses and clips with tremendous pressure. Eliminate burnt fuses and clips — unnecessary shutdowns and wasted current. Use KLIPLOKS everywhere! They're cheap insurance against waste of power, time and replacements.

WRITE FOR Bulletin No. 206-Y the "Inside story of TRICO *Powder-Packed* Fuses" and 257-C on KLIPLOK CLAMPS.

TRICO FUSE MFG. CO., Milwaukee, Wis.... In Canada: IRVING SMITH LIMITED, Montreal

TRICO REG. U.S. PAT. OFF. POWDER PACKED FUSES — STOP WASTED KILOWATTS AND WASTEFUL SHUTDOWNS

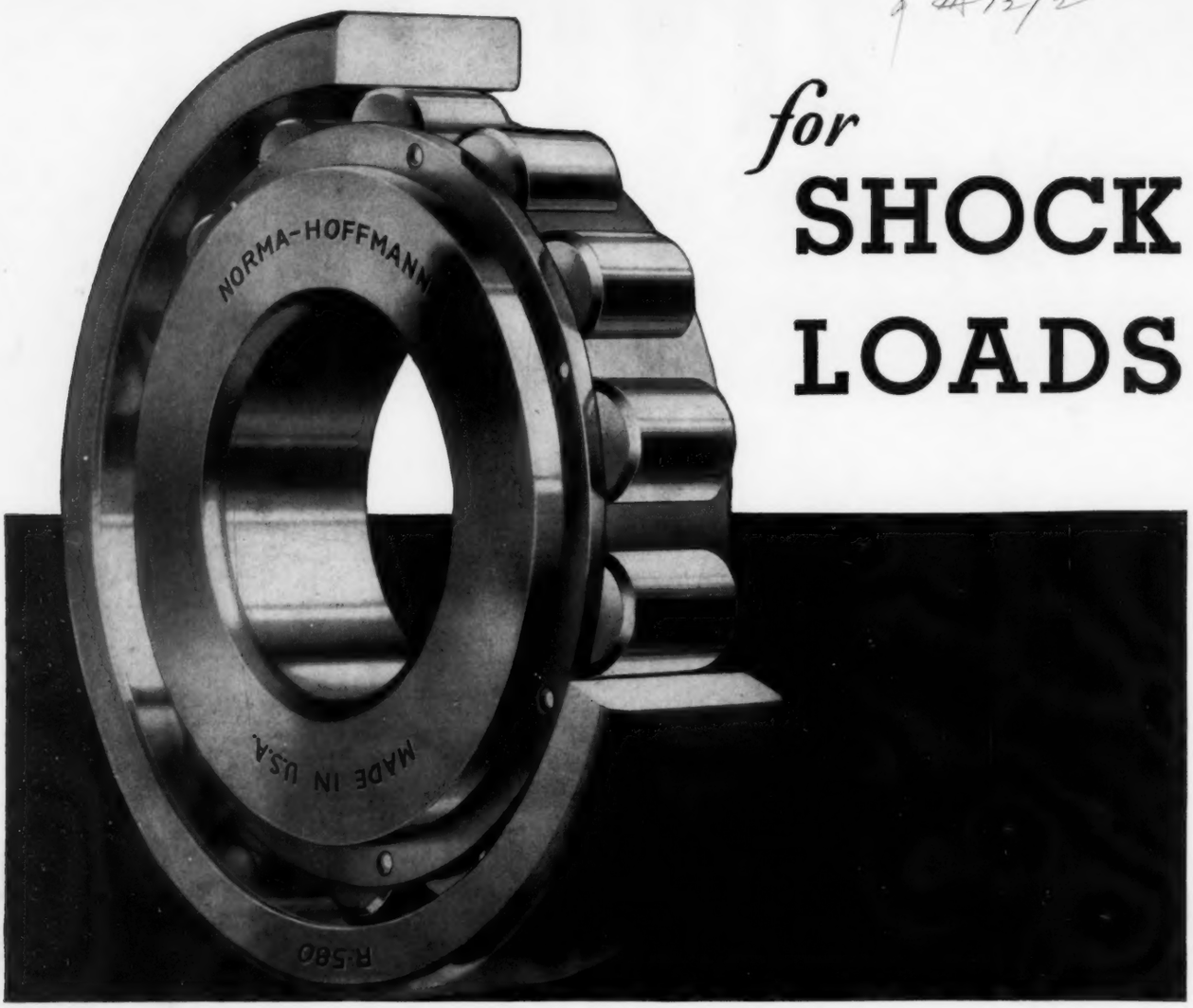
POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.



for SHOCK LOADS

ADD shock load and vibration to an extremely severe steady load—and you have a set of conditions that tests the strength and endurance of any bearing. It is under such conditions that NORMA-HOFFMANN PRECISION ROLLER BEARINGS show their superiority.

Equipped with solid cylindrical rollers between cylindrical races, NORMA-HOFFMANN ROLLER BEARINGS provide maximum load contact area—which means correspondingly increased capacity for both steady loads and overloads, together with greater shock resistance than any other type of single-row bearing affords.

Moreover, they employ a heavy-duty, balanced, extruded bronze retainer—riding on the inner ring shoulders and relieving the rollers of its weight—that insures added durability. And their PRECISION qualities make them suitable alike for low and high speeds. . . . . Write for the Catalog. Let our engineers work with you.

"NORMA-HOFFMANN"

PRECISION BALL, ROLLER and THRUST BEARINGS

NORMA-HOFFMANN BEARINGS CORPN., STAMFORD, CONN. U.S.A.